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Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 12
JAN.
1939
No. 1

SPECIAL ISSUE :: IN TWO PARTS :: PART ONE

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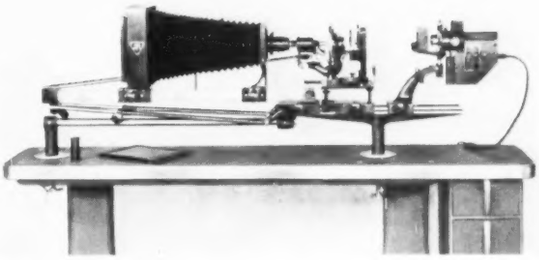

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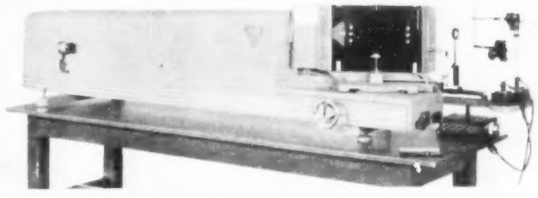

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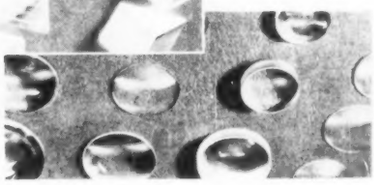

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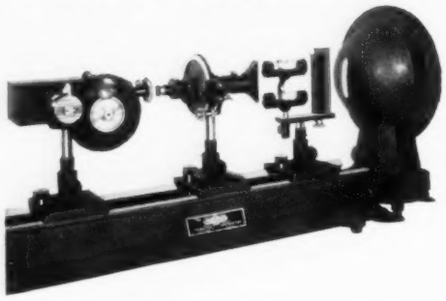

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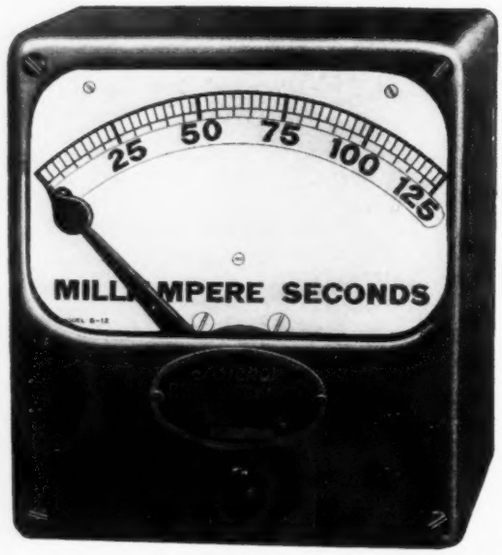

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Instruments

THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 12 No. 1

JANUARY 1939

SPECIAL ISSUE
IN TWO PARTS :: PART ONE
Theme: "What Instruments Do for American Industry"

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Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. BEHAR, Editor

Technological EMployment

FOR years *Instruments* has been showing that technology creates jobs; asserting that those who cry "technological unemployment" have ulterior motives of a sinister, anti-American sort.*

We had written a polished, polite, emotionless editorial for this Special Issue but tore it up in a fit of patriotic indignation when we saw the Jan. 10 "Washington Merry-go-round" syndicated column by Pearson and Allen, containing the following:

> Roosevelt had before him a confidential economic study which . . . warned that there would be little improvement in the unemployment problem during 1939. Continued unemployment was attributed to two factors: technological developments in industry which are steadily wiping out jobs, and the annual influx of young workers . . .

We don't know the alarmists referred to, but we know that they're all wrong.

If we are to have "continued unemployment" it will be chiefly because of millions of dole-made unemployables, because of continued persecution of industry and in spite of the fact that technological developments in industry are steadily creating new jobs!

Let no one dare accuse us of political partisanship! Several times in 1933 and several times since, this page has endorsed most objectives and certain specific policies of the Administration. What we declared in January 1934 still goes:

> We are all for the Roosevelt Reconstruction idea of equitably spreading both purchasing power and leisure, but . . . to increase both leisure and industrial activity we must adopt more and more leisure-producing instruments and control devices.

In this Special Issue, prominent authors report what instruments do for their respective industries; and the symposium as a whole shows that to the nation as a whole instrumentation is a *pure* blessing. We invite the attention of the President and Congress, of Governors and State legislatures, and of other leaders, to the findings of these authors. Here, at last, is "competent evidence" desired by legislators and executives—an overwhelming mass of it!—from which we quote a few really typical extracts:

> Use of instruments has materially helped the workman in gaining confidence in himself during the firing operation and permits him to operate more units and turn out a larger amount of perfect ware, both of which contribute to a reduction in cost—a reduction which is eventually reflected in the wages he receives. . . . Reduction in cost makes a wider market available, permits the industry to employ more workmen. Therefore, the instrument should not be thought of as displacing men . . . but as a means of increasing the number of wage-earners in a particular industry.[1]

> Reaction, filtration, distillation, evaporation, crystallization, drying—all are under instrumental control. The uninitiated might wonder that any human operators would be required at all. . . . [But] men must still be present to supervise and service the instruments and keep a watchful eye on things in general.[2]

> Instrumentation is synonymous with progress, has contributed to safety, cleanliness, better working conditions, more pay per hour, and more leisure for the men employed by the industry, while satisfying the requirements of the steel consumer for a better product at reduced cost.[3]

> Through instruments many uncertainties of the human element have been eliminated and the safety of plant operation has been increased. Without instruments modern mass production of the many articles in common use, as well as articles made to highest standards and precision, would be impossible.[4]

> Present-day competition makes it imperative that we produce the best quality at the lowest cost; the proper use of modern industrial instruments will go a long way in helping us to achieve these ends.[5]

> They [instruments] have also made it much safer and easier for the operator.[6]

> An increase in the number of men demanded for the maintenance of the instruments. . . . Better educated group of men. . . . Modern instrumentation is so complex and multiform that refiners feel a distinct need for instrument courses in the universities.[7]

> Instrumentation of the power industry does not supplement labor to the extent that it increases employment directly in enlarged and new stations. . . . Indirectly, additional labor is required in industries made possible by cheaper power and the developments of electrical science.[7]

> Curing time has been reduced, hard manual work has been largely eliminated . . . permitting the operator to maintain schedule without having to go through a complicated hard-to-remember, fatiguing routine for each unit.[8]

> Hard to visualize today's production methods without the benefit of instruments. The steady flow of materials from the receiving platform to the warehouse and a satisfied customer is only possible if uniformity is maintained.[8]

> Normal operation of airplanes is becoming more and more dependent upon instruments and controllers.[9]

> The whole economy, reliability, and safety of rail transportation is dependent on the functioning of apparatus and instruments.[10]

*See, in particular, Dec. '35 and Feb. '36 editorials on radio-ranting rabble-rousing "Mr. X and Doctor Y and Father Z." There's no longer any doubt, today, that such fanatics not only fear progress, not only despise the American way, but hate America, love totalitarianism and serve European dictators.

[1]Norton (Ceramics)
[2]Mastin (Chemicals)
[3]Conway (Iron & Steel)
[4]Macfarlane (Machinery)
[5]Marsh (Non-ferrous metals)
[6]McCoy (Petroleum)
[7]Lincoln (Power)
[8]Bosomworth (Rubber)
[9]Brombacher (Air Transportation)
[10]Grondahl (Rail Transportation)

F. K. VIAL
Winner of the $200 First Prize

R. K. HELLMAN (2nd Prize)
W. E. STACKHOUSE (3rd Prize)

Instrumentation Contest judges and officials in Hotel Commodore, New York, Dec. 6, 1938 (in the morning, before their faces showed the strain of their work).
Left to right—Standing: Sprague (J), Rimbach (O). *Seated:* Béhar (J), Pigott (J), Roberts* (O), Briggs (Chmn J), Grebe (J).
*President of the Scientific Apparatus Makers of America.

"Grand *Young* Man" of Railroad Research Wins First Prize in Essay Contest

IN a New York hotel conference-room, late in the afternoon of December 6, seven weary men — five judges and two officials—sighed with relief when, after scrutinizing manuscripts all day, they reached final agreement on twelve prize-winning essays and on sixteen honorable mentions. They had scanned many lengthy entries and some brief ones; some purely textual, others accompanied by photographs and diagrams. They were tired. Yet they burned with curiosity as the moment came at last for opening the sealed name-envelopes. Most eager were they to know who had written the outstanding cupola-control essay to which they had unanimously and admiringly awarded the first prize.

One by one the envelopes were opened, the hidden names and addresses were withdrawn and each slip was pinned to the manuscript bearing the same number. When the identity of the first-prize winner was disclosed, one or two exclaimed "I'm not surprised!" Chief surprise was that entrants represented not only every section of the United States but three foreign countries! To make a long report short, here are the results:

FIRST PRIZE, $200

"Automatic CO_2 Compensator for Cupola Control"—F. K. VIAL, vice-pres. in charge of research, Ass'n. of Mfrs. of Chilled Car Wheels, Chicago.

SECOND PRIZE, $100

"An Audio-frequency Spectrometer"—R. K. HELLMAN, elec. engr., Transatlantic Research, Inc., New York City.

THIRD PRIZE, $50.00

"A Hydrogen Sulphide Recorder"—Wilton E. STACKHOUSE, technician, United Gas Improvement Co., Philadelphia.

FOUR FOURTH PRIZES, $25.00 each

"Automatic Control Applied to the Diesel Engine"—George B. Bailey, pres., Thermal Engineering Co., Boston.

"Application of a Multi-pointer Gage for Speed Measurement"—H. A. Kleinman, engr., United Power Mfg. Co., Moline, Ill.

"A Sensitive Method of Flow Control"—M. G. Mastin, chemical engr., Westvaco Chlorine Products Corp., South Charleston, West Va.

"Sugar Boiling by Instrument Control"—Walter E. Smith, technologist, C. Brewer & Co., Ltd., Honolulu, Hawaii.

FIVE FIFTH PRIZES, $10.00 each

"Relative Volumetric Gas Analysis by Cascaded Absorption & Oxidation Recorded by a Pressure Recorder"—Sherman Chase, steam engr., Carnegie-Illinois Steel Corp., South Chicago.

"Sound Frequency Measurement"—Harry C. Gray, stress analyst, Wright Aeronautical Corp., Paterson, N. J.

"Ground Megger as a Signal Generator in Locating Buried Conductors"—G. J. Gross, transmission engr., Penn'a Water and Power Co., Baltimore.

"The Steam Engine Indicator as a Differential Pressure Gage"—Wm. B. Hess, test engr., Safe Harbor Water Power Corp., Conestoga, Pa.

"An Unusual Application of a G-E Torque Balance Watt-telemeter"—Charles Wasserman, tech. asst., Cons. Gas Electric Light & Power Co., Baltimore.

Official report on The First (1938) Instrumentation Contest.
(Sponsored by the Industrial Instrument Section of the Scientific Apparatus Makers of America; conducted by Richard Rimbach, publisher of *Instruments*. JURY OF AWARD: *Chairman*, L. J. Briggs, Director National Bureau of Standards; *Members*, M. F. Béhar, Editor *Instruments*; W. E. Forsythe, Physicist, Nela Park Research Dept., G-E Co.; J. J. Grebe, Dir. Phys. Research Lab., Dow Chem. Co.; R. J. S. Pigott, Head Eng. Dept., Gulf Research & Div. Co.; P. T. Sprague, Chmn. Industrial Instrument Sec., S.A.M.A.)
(Extract from Contest Rules: "The Instruments Publishing Co. and the Sponsors reserve the right to publish any article submitted." Some will be published in *Instruments*; others, especially those of interest to specific industries, in magazines of special scope.)

THE WINNERS!

Born in Illinois in 1864, Vial took his B.S. a mere fifty-four years ago; his C.E. even more recently. Since then, of course, he hasn't had the time to do much, but the record of his achievements which we received from his office fills three pages of single-spaced typewriting. Items: engineering jobs with railroads 1887-1902; in car-wheel industry 1902 to date; eight important patents (and lots of others!); first to successfully apply the hot-blast to the cupola; first to commercially desulphurize cupola iron; runs the lab where all pyrometers for his industry (50 plants) are calibrated; runs his industry's research lab; active on various university, company and ass'n. research projects; on many society and government technical committees . . . etc., etc.

After taking his degree in 1932, Hellman worked on gas-discharge research problems in Aachen (with Rogowski who introduced the high-speed c-r. oscillograph in Europe). In 1933, he joined the Siemens & Halske lab in Berlin, where he developed acoustical, a-f. and r-f. measuring equipment. Since 1937 with Transatlantic Research, Inc., N. Y., in charge of engineering related to export of special radio and h-f. equipment, also consulting and design work on sound and radio measuring equipment.

Born 35 years ago in Pittsburgh, Stackhouse took his E.E. at U. of Penna. and has been U.G.I.'s chaser-of-impurities-in-gas, developing new methods so distinctive that his Contest essay came near being disqualified as "not new" when a judge *(mea culpa!)* remarked: "This set-up reminds me of one described a couple of years ago by a U.G.I. man named Starr or Stark. However, it's for a different gas so let's hold it for final grading." No wonder it was reminiscent of the article by Stackhouse in our June 1936 issue: it bore the same master touch!

Instrumentation as a Factor IN America's CHANGING Technology

By G. PERAZICH and H. SCHIMMEL
Authors of
Industrial Instruments & Changing Technology
a report of Works Progress Administration
NATIONAL RESEARCH PROJECT

This article was prepared with the permission of the Director of the National Research Project.

"THEN & NOW" HEADPIECE BY ETHEL LEVINSON

Function of Measurement

CHIEF among the characteristics of modern technology has been the gradual adoption of quantitative methods of specification and control and intensification of organized industrial research, particularly in mass production industries. Without the development of appropriate tools, however, quantitative analysis and control as practiced today would not have been made possible. In many instances, industrial instruments are employed as tools of measurement technique and the development of cost accounting in modern industry has also been greatly aided by the introduction of measuring devices.

In practically all production processes there are present a large number of variables; the establishment of correct relationship among them is frequently an essential factor which contributes to the achievement of efficient production. Unaided by instruments, human observation is not sufficiently rapid or accurate to measure a large number of variables, particularly as they are found in many recently-developed processes such as those employed in the manufacture of synthetics or alloy steels. In this sense it may be said that just as the development of a machine, such as the steam engine, has made possible the extensive application of mechanical power by removing the restrictions imposed upon production due to limitations of human and animal energy, so instruments have played an analogous rôle in regard to human perception and judgment. They have, in short, removed the restrictions imposed upon many production processes by man's limited ability to observe and control physical phenomena.

Among important functions of instruments is their application for research and experimentation. Without accurate measuring devices, many new products and processes would not have been possible. Indeed, without the use of measuring and controlling devices it would be impossible to generate and distribute electric power. Electric power is subject to instantaneous application and to more precise control than any other form of power. It is these attributes which make the use of electricity basic to the application of many instruments in industry, and which also make the production and distribution of power itself dependent upon instrumentation. Considering the function of electricity in our economy, it will be readily seen that measuring and controlling devices have become of prime importance.

The Technological Basis for Instrumentation

Technology poses practical problems to the scientist; the solution of these problems in turn serves to establish the basis for new techniques and higher levels of technological development. What is today a theoretical problem in which only a few scientists are interested, tomorrow becomes a new machine or a new process which may have far-reaching effects upon production techniques.

Science increasingly requires the use of precise technical terms based on a complex series of measurements which cannot be expressed in terms of human sensation. The rapid advance of science since the sixteenth century brought with it the development and perfection of a large number of new instruments. Many of these instruments were a direct outcome of major scientific investigations and discoveries which in turn had their origins in contemporary technological advances.

Measurement and control associated with instrumentation depends largely on the more general factors influencing the development of technology. This may be illustrated by a brief analysis of the methods of production in the old handicraft technology in which measurement and instrumentation were little known, and of modern technology based on the mass production methods.

In the handicraft economy, production processes were carried out primarily as traditional arts by single individuals or by small groups of people to whom the standardization and objectivity associated with measurement were unknown. Manufacture was conducted on a restricted basis and in the majority of cases the family produced what goods were required for the direct satisfaction of its needs. Even the specialized craftsman who made commodities destined for consumption by others usually performed his work under the supervision of the consumer. In either case, the user could observe directly whether or not the product met his specifications.

The advent of the factory system marked the beginning of extensive changes in the character and organization of production. Goods were no longer produced by their users or directly for them but for a market which was continually growing in scope and magnitude. Consumers ceased to have immediate contact with producers and thus it was necessary that the properties of finished commodities be designated according to specific standards. As production became more

complex, an increasing number of raw materials and intermediate products needed standardization. The drive toward precision, which had its beginnings in the development of mass production methods, is clearly illustrated by the practice in the manufacture of interchangeable parts.

It is clear then that the rise of mass production invested instruments with enhanced economic significance since goods were now produced not with the tools owned by the individual worker who, because of his skill, was able to produce a high-quality product, but with the machine owned by the entrepreneur whose interest was to render the efficiency of a machine or a process independent of the skill of individual operators. When the operation of a machine becomes standardized by the application of instruments, any number of available workers can operate it with a high degree of efficiency.

Economic Functions of Instruments

The major function of industrial instruments is that of auxiliary equipment to major production units. With the help of these devices, various types of operating economies are feasible. Among some of the outstanding economies could be mentioned: the increased rate of operation of machinery and of processes, reduction in waste of materials, fuel and power, continuity of operation and better utilization of capital equipment. Instruments frequently function to coördinate the rates of speed of one machine with another or one process with another, thus making possible the development of continuous processes which permit more efficient production.

One of the important methods in decreasing waste by means of instruments is by keeping operating conditions uniform throughout the production cycle. In the clay and porcelain products industry, for example, temperature changes in the kiln, which often occur without proper fuel control, cause defects in the products; whereas pyrometer-controlled kilns not only cut down spoilage but produce a better quality product with smaller fuel costs. In some industries, fuel and power account for a relatively large proportion of total operating expenses. Instruments make possible important savings in these items by increasing the amount of utilizable heat derived per unit of fuel. Central stations used in 1936 less than 1.5 lbs. of coal per kwh. of electricity as compared with 3 lbs. in 1920 and 6.5 lbs. in 1902. There have been also savings in blast furnaces where fuel consumption declined from 3,400 lbs. per ton of pig iron in 1920 to less than 3,000 lbs. in 1936.[1] Economies of this nature can be accomplished through a variety of auxiliary devices. Gas analysis meters, for example, have served to improve combustion and thereby to raise the level of fuel efficiency.

In the service industries, notably power generation and communication, the maintenance of uninterrupted operation is more than a measure of economy, it is an end in itself. And in the chemical industries, a temporary cessation of operations may result in the spoilage of an entire batch being processed. In the two fields just mentioned, therefore, a break in operating continuity would be serious; elsewhere it involves expenditures which the use of instruments can diminish or eliminate entirely. Instrumentation, for example, can help to reduce breakdowns of machinery and equipment and thus obviate a good portion of repair and maintenance charges. At the same time, it can increase efficiency in the utilization of labor since it cuts down periods when workers are idle. Continuity of operation tends also to augment the effective capacity of machinery and in this sense contributes to better utilization of capital equipment.

Certain instrument applications are specifically intended to effect economies in the utilization of capital equipment. Indeed in many industrial establishments, before additional equipment is purchased, the existing machinery is carefully analyzed with a view to determining whether it is being used to its fullest capacity. Frequently such analysis reveals that the capacity of equipment already functioning may be expanded to the point where additional installations would no longer be required. In addition to the increase in capacity, there are other significant savings in capital costs. The life span of equipment can be extended by more uniform regulation of its function in the production process. Sudden changes in the speed of operation, supply of material and fuel, temperature and pressure, contribute to wear and tear of equipment. Uniformity of operation, on the other hand, provides the basis for smooth functioning of machinery with a minimum of wear. In the rolling mills, for example, pressure blocks serve to protect the equipment against excessive wear. By observing the instruments, an operator can prevent undue pressure on the rolls and in this way reduce the wear on both the bearings and the rolls. Moreover, since there are fewer shutdowns for repairs, the effective roll capacity is increased as well. In a six-stand mill producing 400,000 tons of rolled steel a year, the use of pressure blocks not only saves $45,000 a year, but also augments the effective capacity of the rolls.[2]

Instrumentation also helps in reducing maintenance charges by maintaining uniform operating conditions. In one plant it was found that boilers equipped with automatic controls needed no refractory repairs at the end of a year while similar boilers operating under manual control in the same plant required re-bricking every three months.[3]

Effects on Labor Requirements

The effect of instrumentation on labor requirements depends on other economic factors. Although instruments help in reducing labor requirements *per unit*, the effect of this on over-all employment opportunities depends on subsequent changes in the volume of output. In times of expanding output when new production levels are reached, or when new industries are developed with the aid of instruments, opportunities for employment will tend to increase both in the manufacture of instruments themselves and in the manufacture of other types of equipment used in these new industries. On the other hand, during the periods of declining output, when pressure for economies in production makes necessary the installation of instruments for the purpose of reducing costs, their function as auxiliary devices would have the opposite effect.

Instruments can be and have been a stimulus to obtaining new peaks in production by aiding in the increase of labor productivity and in the development of new products and services. During the last eight years, notably from 1929-1935, however, their function in the industries which are the largest purchasers of instruments has been to reduce costs and the per-unit labor associated with production.

If attainment of greater levels of production and higher living standards were the primary objectives for the application of available industrial technology, progressive instrumentation would be an obviously beneficial social goal. The future rôle of industrial instruments in the economy and their effect on employment will depend, however, upon the extent to which such objectives are in conflict with immediate pressures for cost reductions through economies in labor utilization regardless of the levels of production and employment.

PART II—TRENDS*

Sales of Industrial Instruments and Output of all Instruments, 1909-35

Table 1 shows that except for the periods of general business depression, 1919-21 and 1929-33, rapid expansion was characteristic of both industrial instruments and all other instruments. The upward trend of industrial instrument sales, however, has been much more striking, increasing from 4.5% of the total output of all type instruments in 1909 to 25.7% in 1935.

[1] Nicholas Yaworski, Vivian Spencer, Geoffrey A. Saeger, and O. E. Kiessling. *Fuel Efficiency in Cement Manufacture, 1909-1935.* Works Progress Administration, National Research Project and Department of the Interior, Bureau of Mines, Philadelphia, April 1938. Table A-1, page 70.

[2] "New Device Indicates and Records Rolling Levels", *Steel*, Vol. 96, April 22, 1935, pages 43-52.

[3] "Maintenance by Automatic Control." *Chemical Age*, Vol. 32, Feb. 16, 1935, pages 147-8.

*The methods and computations employed in preparing the statistical data presented here are described in more detail in *Industrial Instruments and Changing Technology* (Works Progress Administration, National Research Project, October 1938).

Table 1—SALES, 1909-35

Year	Sales of industrial instruments[a] (Thousands of dollars) (1)	Index 1929=100 (2)	Output of all instruments[b] (Thousands of dollars) (3)	Index 1929=100 (4)
1909	342	1.8	7,573	9.2
1914	822	4.4	12,621	15.3
1919	4,402	23.6	44,201	53.7
1921	4,155	22.3	34,992	42.6
1923	7,907	42.4	55,168	67.0
1925	9,404	50.4	70,253	85.4
1927	12,272	65.8	81,017	98.4
1929	18,653	100.0	82,298	100.0
1931	**10,454**	**56.0**	**36,216**	**44.0**
1933	6,880	36.9	22,480	27.3
1935	10,989	58.9	42,779	52.0

[a]Adjusted field data representing sales of seven companies. In 1935 this field sample equaled approximately 55% of all industrial instruments sold in the U. S.

[b]Census of Manufactures data adjusted to exclude surgical and dental instruments and optical goods; does not include gas and water meters, electrical meters and machinists' gages.

Table 2—TREND OF SALES OF INDUSTRIAL AND LABORATORY INSTRUMENTS, 1920-35[a]
(Index numbers, 1929 = 100)

Year	Industrial instruments (1)	Laboratory instruments: Industrial laboratories (2)	Laboratory instruments: Educational laboratories (3)
1920	34.3	n.a.	56.2
1921	22.3	36.9	67.5
1922	30.0	49.1	**71.6**
1923	42.4	59.9	80.7
1924	41.6	59.1	**83.5**
1925	50.4	65.5	87.8
1926	63.0	73.0	91.6
1927	65.8	76.0	95.1
1928	**74.9**	**86.3**	96.8
1929	100.0	100.0	**100.0**
1930	81.9	87.4	103.7
1931	56.0	63.8	103.5
1932	33.7	52.6	**69.8**
1933	36.9	55.0	55.4
1934	48.7	70.6	**55.4**
1935	58.9	84.2	**58.7**

[a]Based on field data. Supply items are included.

n.a. Data not available.

Table 3—DISTRIBUTION OF INDUSTRIAL INSTRUMENT SALES BY INSTRUMENTS PROPER AND SUPPLIES AND REPAIR PARTS, 1922-35[a]
(Percent)

Year	Total (1)	Instruments proper (2)	Supplies and repair parts (3)
1922	100.0	68.7	31.3
1923	100.0	71.7	28.3
1924	100.0	71.9	28.1
1925	100.0	71.5	28.5
1926	100.0	70.2	29.8
1927	100.0	69.8	30.2
1928	100.0	69.0	31.0
1929	100.0	67.0	33.0
1930	100.0	65.8	34.2
1931	100.0	63.3	36.7
1932	100.0	54.8	45.2
1933	100.0	52.7	47.3
1934	100.0	54.6	45.4
1935	100.0	56.9	43.1

[a]Based on field survey.

Table 4—DISTRIBUTION OF INDUSTRIAL INSTRUMENT SALES BY FUNCTION, 1923-35[a]
(Percent)

Year	Total (1)	Indicators (2)	Recorders (3)	Controllers (4)
1923	100.0	28.6	63.7	7.7
1924	100.0	30.3	59.7	10.0
1925	100.0	29.5	58.0	12.5
1926	100.0	27.2	57.0	15.8
1927	100.0	26.0	54.4	19.6
1928	100.0	24.3	54.3	21.4
1929	100.0	23.5	54.9	21.6
1930	100.0	23.9	54.4	21.7
1931	100.0	24.8	52.2	23.0
1932	100.0	24.3	48.9	26.8
1933	100.0	22.5	47.6	29.9
1934	100.0	21.9	46.5	31.6
1935	100.0	21.6	45.1	33.3

[a]Based on field data.

Statistics Compiled by National Research Project

Table 5—ANALYSIS BY FUNCTION AND SUBJECT OF MEASUREMENT OF INSTRUMENT SALES, 1935[a]
(Percent)

Type	Total (1)	Indicating (2)	Recording (3)	Controlling (4)
All instruments	100.0	21.6	45.1	33.3
Flow	100.0	5.5	79.8	14.7
Pressure	100.0	13.3	58.5	28.2
Temperature	100.0	29.0	31.8	39.2
Humidity	100.0	.....	36.8	63.2
Liquid level	100.0	7.8	18.3	73.9

[a]Computed from sales data supplied by the Industrial Section of Scientific Apparatus Makers of America, and other data obtained in the course of the field survey.

Table 6—DISTRIBUTION OF INSTRUMENT SALES BY INDUSTRY, 1935[a]
(Percent)

Industry	Total	Industry	Total
Metals[b]	26.5	Ceramics	1.2
Power[c]	16.3	Brewery and distillery	1.2
Petroleum[d]	16.3	Sugar	0.6
Chemicals	5.0	Lumber	0.6
Food	4.7	Paint and varnish	0.2
Textile	2.2	Laundry	0.2
Paper and pulp	1.7	Leather	0.1
Rubber	1.7	Miscellaneous[e]	19.9
Glass	1.6	*Total*	100.0

[a]Based on field data.

[b]Primarily sales to iron and steel industry and automotive industry.

[c]Central stations and industrial power plants.

[d]Primarily sales to petroleum refineries.

[e]Includes industrial laboratories (6.4%), refrigeration (0.8%), air conditioning (1.2%) and government (0.5%). The percentage remaining represents export sales and minor industry sales not separately tabulated.

Table 7—INDEXES OF SALES OF INSTRUMENTS TO SPECIFIC INDUSTRIES, 1923-35[a]
(Index Numbers 1929 = 100)

Year	Metals (1)	Power (2)	Petroleum (3)	Chemicals (4)	Glass (5)	Ceramics (6)
1923	37.3	53.4	22.7	11.8	65.3	83.0
1924	30.7	54.5	20.1	11.3	47.1	68.2
1925	34.1	66.2	37.4	14.6	51.7	64.4
1926	45.1	72.9	67.6	21.6	73.7	82.4
1927	50.1	86.1	44.2	31.2	90.7	85.4
1928	71.2	93.7	56.2	56.1	94.6	96.0
1929	100.0	100.0	100.0	100.0	100.0	100.0
1930	62.0	93.4	85.1	52.8	51.6	62.2
1931	37.3	64.5	49.7	30.3	29.0	32.9
1932	26.2	36.1	31.2	19.2	25.3	17.4
1933	23.8	37.9	29.0	22.0	36.0	20.0
1934	34.1	46.1	31.8	39.3	51.1	32.8
1935	55.8	55.7	41.0	35.2	46.1	47.3

[a]Based on field data. Classifications are the same as those used in Table 6.

The most rapid growth, measured in terms of dollar value, took place during the period 1914 to 1919 when the production of all instruments rose by 250% while sales of the industrial type increased by 435%. Part of this expansion must be attributed to the rise in price level which took place during that period, but the chief factor was the greatly increased demand for instruments created by the World War. Production of war materials according to more stringent specifications, a rapid increase in industrial capacity, a shortage of skilled labor, pressure for fuel economy—all of these and a number of other factors provided a powerful impetus toward instrumentation in industry.

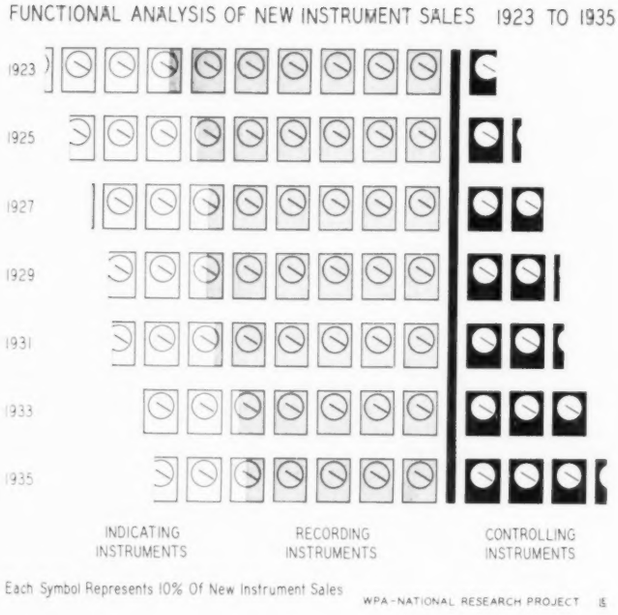
The subsequent decade, 1919 to 1929, was also one of considerable expansion particularly for the sales of industrial instruments which increased by more than 300%; the corresponding increase for all instruments, however, was only 80%. A partial explanation of the difference in the rate of expansion between the instrument industry as a whole and the industrial instrument industry is brought out by an analysis of the sales trend of laboratory instruments for the period 1920-35. Data obtained in the course of the field survey and presented in index form in Table 2 show that during the period 1920-1929 the sales of industrial instruments proper increased more rapidly than did those of laboratory instruments.

It will be noted from the foregoing data that industrial instrument sales tend to fluctuate more markedly than do the sales of the laboratory type. The sales of laboratory instruments to industry undergo approximately the same year-to-year fluctuation as do industrial instruments, while sales to educational laboratories apparently respond much more slowly to changes in business conditions. This is probably due to the fact that educational institutions draw up their equipment budgets a year or two in advance.

Sales of Instruments Proper as Compared with Supplies, 1922-1935

The sales of the instrument industry may be divided into instruments proper, and supply items and repair parts. These two categories should be distinguished because of their different economic functions. The purchase of instruments proper represents a capital investment in auxiliary equipment while supplies, particularly chart paper, ink, and oil, represent items which are continually being used in the process of operation. Repair parts, which are necessary for maintenance and upkeep of instruments, also represent an item for which there is a relatively stable demand. Table 3 shows a distribution of industrial instrument sales into these two different classes which have been derived from data obtained in the field survey.

It is seen that during the period 1923 to 1929, the percentage of supplies and parts sales increased. This took place probably as a result of the needs of the accumulated sales of instruments. The proportion of supplies and parts purchases rose still more rapidly during the period 1929 to 1932 because of the more stable demand for supplies and parts. Although many manufacturers did not invest in instruments during the lean years, they continued to use the instruments they had and therefore had to purchase supplies and parts for them.



Distribution of Industrial Instrument Sales According to Functional Types

The sales of instruments proper may be further broken down according to their function either as indicators, recorders or controllers. It was found that the sales of controlling instruments increased much more rapidly than did those of indicators and recorders prior to 1929. During the subsequent depression, sales of this type declined less rapidly than did those of indicators and recorders, and finally after 1933, the controlling instruments experienced a greater recovery. These developments are reflected in a regular increase in the proportion of total sales represented by controllers. Whereas this type of instrument had constituted only 7.7% of the total value of industrial instrument sales in 1923, by 1935 they represented 33% of the total. The wide utilization of the control type instrument for automatic regulation of industrial processes is essentially a development of the post-war period. Although there were a few instruments of this type in use at the beginning of the twentieth century until about 1919, they represented a negligible proportion of industrial instrument production.

Although controllers are gradually superseding the simpler indicating and recording types, this development seems to vary considerably with the subject of measurement.

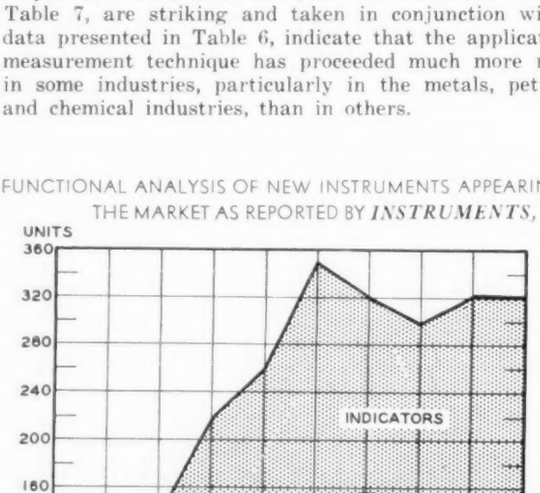
For example, as Table 5 shows, only 15% of the flow meters sold in 1935 were controllers, whereas this type represented 74% of the liquid level instruments. Such variations are conditioned by the different applications which instruments find according to their subject of measurement. For example, flow meters are used chiefly for accounting and analytical purposes and thus the recording type predominates, while liquid level instruments are installed primarily for direct process regulation, and it is in this field of instrumentation that the shift to the controlling type has been most pronounced.

Instrument Sales to Individual Industries, 1923-35

A distribution of instrument sales according to the principal purchasing industries for the year 1935 is given in Table 6. This tabulation indicates that the largest purchasers of instruments are the mass production and process industries. Definite conclusions as to the relative magnitude of the purchases of the different industries, however, are unwarranted, first, because instrument manufacturers usually specialize in equipment particularly suitable for certain processes and therefore the industry distribution of the sales of the companies covered in the field sample may not be representative of that of all industrial instrument sales. Furthermore, the year 1935 alone is treated here and it is probably true that the relative magnitude of purchases of individual industries varied more over longer periods.

Data obtained for earlier years, while insufficient for a complete distribution of sales by industry, have been employed in the case of six of the industrial groups, for the construction of indexes which show the trend of sales during the period of 1923-35. See Table 7. The purchases of these six industries exhibit the rising trend and cyclic fluctuations which are characteristic of total industrial instrument sales. Separately considered, however, they reflect definite variations in rates of instrumentation. It will be noted, for example, that from 1923 to 1929, the purchases of the chemical industries were increased by approximately 750%, while purchases of the ceramics industry were increased by only 20%. These differences, as well as others shown by Table 7, are striking and taken in conjunction with the data presented in Table 6, indicate that the application of measurement technique has proceeded much more rapidly in some industries, particularly in the metals, petroleum and chemical industries, than in others.

FUNCTIONAL ANALYSIS OF NEW INSTRUMENTS APPEARING ON THE MARKET AS REPORTED BY *INSTRUMENTS*, 1928-37



While instrument sales dropped in 1930-33 (see Tables 1 and 2) there was the greatest increase in new devices reported by the magazine *Instruments*. On the other hand there has been a simultaneous rise in controller sales (upper two charts on this page) and percent of controllers among new devices.

WHAT INSTRUMENTS DO FOR INDUSTRY

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WHAT INSTRUMENTS DO FOR

The Ceramic Industries

By F. H. NORTON

Associate Professor, Division of Ceramics, Department of Metallurgy, Massachusetts Institute of Technology

PROBABLY the oldest industry in the world, the making of ceramic articles has been considered—like all old industries—an art to be handed down from generation to generation, because the skill required in throwing pottery on the wheel or decorating a vase required many years of training which could only be obtained by direct contact with the manufacturing process.

One of the first men to give serious thought to the scientific aspects of ceramics was Wedgwood in England, who developed his so-called thermoscope consisting of little blocks of unfired clay which shrank to different degrees as the temperature was increased. These pieces were drawn out of the kiln at different times and when they reached the desired shrinkage the firing was stopped. Later, there were developed the so-called pyrometric cones which consisted of a graded series of compositions designed to soften at even temperature intervals. The softening of these cones could be observed from the outside of the kiln and they did not have to be drawn out.

The introduction of the continuous kiln has made accurate pyrometer equipment more necessary than before, and most of the modern ceramic plants are well fitted up with pyrometers to give a continuous record of the temperature, and often with automatic controllers to maintain this temperature within the desired limits.

A few years ago the introduction of instruments for the control of an industrial process was not uncommonly resisted, either actively or passively, by the operating men; because they did not understand and did not trust the indications of what to them was a new development of science; and because they considered the use of instruments a reflection on their own ability to control the process.

More recently, however, the use of instruments has been regarded not only with tolerance but often with enthusiasm because it removes a great deal of the personal responsibility for the process control. For example, in many plants a fireman or burner knows that he will lose his job if he lets the temperature go so far over the desired burning range that a kiln of ware, or the kiln itself, is spoiled in the firing process. This ever-present fear prevents the fireman (unaided by instruments) from handling his equipment to the maximum efficiency as he always hesitates about bringing the heat up to the desired point for fear he will go too high and thus lose his job. The use of instruments, therefore, has materially helped the workman in gaining confidence in himself during the firing operation and permits him to operate more units and turn out a larger amount of perfect ware, both of which contribute to a reduction in cost—a reduction which is eventually reflected in the wages he receives.

There are abundant examples to show that the use of instruments in controlling the manufacturing process in ceramics gives a superior quality of ware and a reduction in cost. In turn this reduction in cost makes a wider market available, and therefore permits the industry to employ more workmen. Therefore, the instrument should not be thought of as displacing men from the production process, but as a means of increasing the number of wage-earners in a particular industry. For example, modern production methods permit the manufacture of a 100-piece set of semi-vitreous china of a particular pattern for a factory cost of $7.50, whereas if this same set had been made by the older hand-made methods with the same wage scale, the factory cost would be two or three times as great and would, therefore, greatly curtail the market for this class of ware.

The Pottery Industry

The pottery industry in the last few years has gone rapidly over to continuous firing methods, which have the advantage of fitting in well with an efficient production system, and in general give a better quality of ware. The modern continuous tunnel kiln when properly designed and properly used gives excellent results and will eventually be used in practically all the pottery industries.

In using the tunnel kiln it is necessary not only to know the maximum temperature but also to know the temperature gradient throughout the kiln itself from entrance to exit, in order to maintain the desired heating and cooling cycle. In most installations the temperature is measured by a series of platinum thermocouples, inserted through the crown at various places in the kiln, connected to a multiple-point indicator or recorder. In the lower temperature zones, of course, base-metal couples can be used, but this would necessitate a change of scale or a different instrument from that used with the platinum couples—a complication which is not usually justified by the saving in cost of the couples themselves.

It should be realized that in most of these installations the platinum couple does not read the temperature of the ware passed through the kiln. In some cases the couple is hotter due to contact with the combustion gases, and sometimes it is cooler due to conduction through the protection tube. When this fact is recognized, however, it is no particular disadvantage, as once a satisfactory temperature schedule is established it can be maintained. Care should be taken, however, not to change the type of protection tube or mounting of the thermocouple without carefully studying its effect on the temperature reading.

It is a usual practice in firing pottery tunnel kilns to pass a set of pyrometric cones through the kiln at regular intervals, an additional check on the thermocouple readings. Cones, however, are useful for another reason. It is sometimes necessary because of an increase or decrease in orders to change the speed of the tunnel kiln, and it is a well-known fact that the more rapid the heating cycle the higher must be the maximum temperature. The cones, however, will approximately follow the maturing of the ware. Therefore, if a tunnel kiln, for example, was speeded up from the rate of one car per hour to the rate of $1\frac{1}{4}$ cars per hour, the temperature in the hot zone would have to be raised a

sufficient amount to give the same cone reading as was obtained at the lower speed. There are, of course, some cases where the maturing characteristics of the ware do not follow the cones with a varying time schedule, but in these cases physical tests of the finished ware will indicate the proper maximum temperature.

Automatic controllers for maintaining a given temperature in the kiln have not been used as much in the pottery industry as they have in heat-treating plants because the gas-fired tunnel kiln holds a fairly constant temperature which can easily be maintained by slight adjustments in the firing. However, some of the more progressive plants have used temperature controllers and it has been definitely shown that a more uniform temperature can be obtained in this way than with hand control, and in the case of ware with a narrow firing range the controller does show a real increase in perfect ware. With good controlling equipment one fireman can take care of a considerable number of kilns.

The pottery industry is constantly striving to produce improved types of ware and many of these improvements take the direction of bodies having a narrow vitrifying range in order to give translucency with freedom from warpage. Such developments will depend more and more on extremely accurate temperature control of the firing process —a control which can only be carried out by carefully designed temperature controlling equipment.

Refractories

The temperature of firing in the refractories industry is generally so high that platinum couples will not give satisfactory service at the maximum temperature zones, although there are a number of installations in the older types of kiln where the platinum couple is protected by a massive tube in such a way that the couple does not reach the temperature of the kiln itself. In this way the couple is protected from the excessive temperature and a correction can be applied which will allow proper burning cycles to be repeated time after time. In the tunnel kilns the platinum couples can be used everywhere but in the hot zone itself. In this location the optical or radiation pyrometer is required. The problem, however, is not a simple one for the reason that in oil- or coal-fired kilns (principally used in the refractories industry) there is luminous flame or smoke which makes accurate readings with the optical radiation pyrometer extremely difficult. The problem can be solved at the lower temperature ranges by sighting into a closed-end tube which has been inserted in the kiln. The modern refractories, however, are being fired at temperatures of 2500-3000°F., where it is extremely difficult to maintain a closed-end tube of sufficient length and thinness of wall to give a precise temperature reading.

The consumers of refractories are continually demanding greater uniformity, which means that the progressive manufacturer must adopt accurate temperature control mechanisms on their kilns.

Heavy Clay Products

The heavy clay products industry has been somewhat slower than the other branches of ceramics in adopting modern instruments for temperature recording and controlling. The reason for this is due probably to the fact that the material has a comparatively long maturing range, and the specifications for the finished product are not as close as for some of the finer wares. The manufacturers are beginning to realize however that in many cases a carefully controlled temperature will give them a more uniform product and will definitely eliminate losses. This is especially true of a ware like terra-cotta where the temperature and atmosphere must be fairly well controlled in order to get a uniform product.

Some other materials such as common face brick have no rigid specification as to physical properties and often a variation in color and texture is really desirable. On the other hand, it is generally thought that water-tight brick walls are obtained with mortar which is adjusted to the particular type of brick, and in order to do this successfully the brick must have a good uniformity in its physical structure. This calls for close control of burning conditions.

The Glass Industry

The glass industry has long recognized the importance of temperature control in the fore-hearth of the tank in order to supply glass of uniform viscosity to the feeder. Due to the fact that the temperature is not excessive at this point, control mechanisms have been worked out satisfactorily.

Not so much has been done, however, in controlling or recording the temperature in the melting section of the tank. Due to the luminous flame, which is considered desirable in glass melting, it is difficult to get a good reading in the open furnace either with an optical pyrometer or radiation pyrometer. Often times, however, with care a position can be selected which is relatively free from luminous flame so that a permanent radiation pyrometer can be mounted to sight on a portion of the roof in much the same way that temperature controls have been developed for the open-hearth furnace. The modern tendency to insulate the glass furnace makes it necessary to prevent excessive temperatures in the melting zone, otherwise the life of the refractories will be materially shortened.

Plant Standardization, etc.

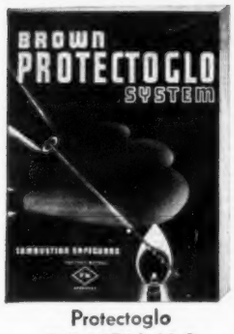
It has been my experience that the majority of difficulties occurring in the ceramic plant with the temperature measuring equipment arise from a lack of understanding of the variations which may occur in the thermocouples of optical pyrometers due to a large number of causes. These variations are bound to occur with the best constructed equipment and must be compensated periodically by checking with some standard. In the case of thermocouples it is desirable to check these perhaps once a month, with a working standard in a special calibration furnace so constructed that the working standard and the plant couple are definitely at the same temperature. This is not an easy thing to do and the greatest care must be taken in the calibration work. The working standard should also be checked, every six months or so, with a master standard certified at the National Bureau of Standards or by the freezing points of pure metals. This master standard should be used for no other purpose than checking the working standard couple. In this way the plant thermocouple can be kept within the desired working limits of temperature by taking account of progressive changes in the couple due to volatilization or effects of furnace gases which will penetrate even the best protection tube.

In the case of the optical pyrometer the same procedure should be followed. That is, the plant instrument should be checked at least once a month with a working standard and the working standard should be compared with a master instrument at less frequent intervals. A convenient method of comparing one pyrometer with another is to set up a thousand-watt projection lamp with a screen of opal glass in front of it cut down with a diaphragm about ¼" in diameter to assure a uniform field. With a rheostat or other voltage controller the apparent temperature of this screen can be varied anywhere from dull red up to 3200 or 3300°F. In comparing the pyrometers care should be taken that the instrument is held in a support directly in front of the diaphragm so that each pyrometer will be in exactly the same position as the standard.

Further improvement is required in instruments for high-temperature recording and controlling equipment to assure the accuracy and ruggedness now associated with instruments for measuring temperatures in the lower ranges. It would also be highly desirable to have thermocouples which could be used up to temperatures of 3000°F. The tungsten-molybdenum couple has been used in the laboratory for this purpose but is not sufficiently stable for continued use in the plant. We also need better refractory protection tubes capable of withstanding temperatures up to 3200°F. without sagging or deterioration. This is especially desirable with sighting tubes for radiation pyrometers.

Another hoped-for improvement is a simplication of the recording optical pyrometer which will allow its use more generally in the ceramic industry.

There is also a real demand for an inexpensive pyrometer to be used by studio potters and schools.



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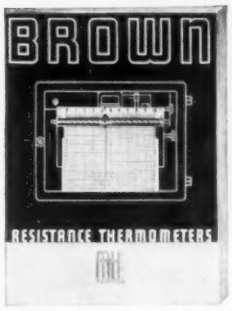

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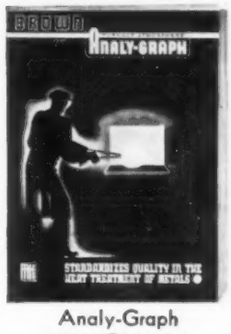

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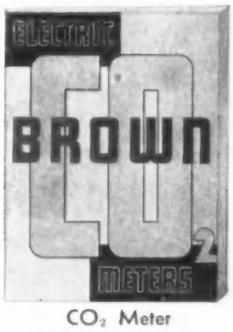

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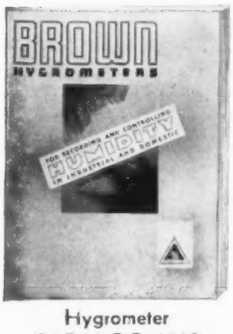

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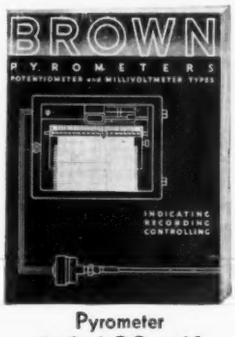

Pyrometer
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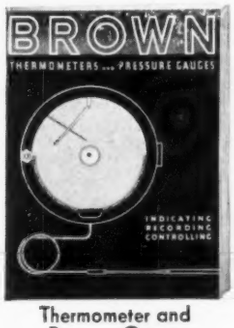

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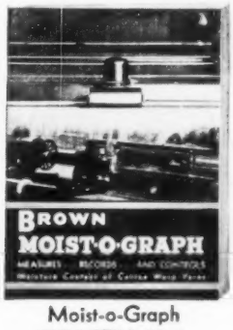

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BULLETIN 93-1

Boiler Regulation
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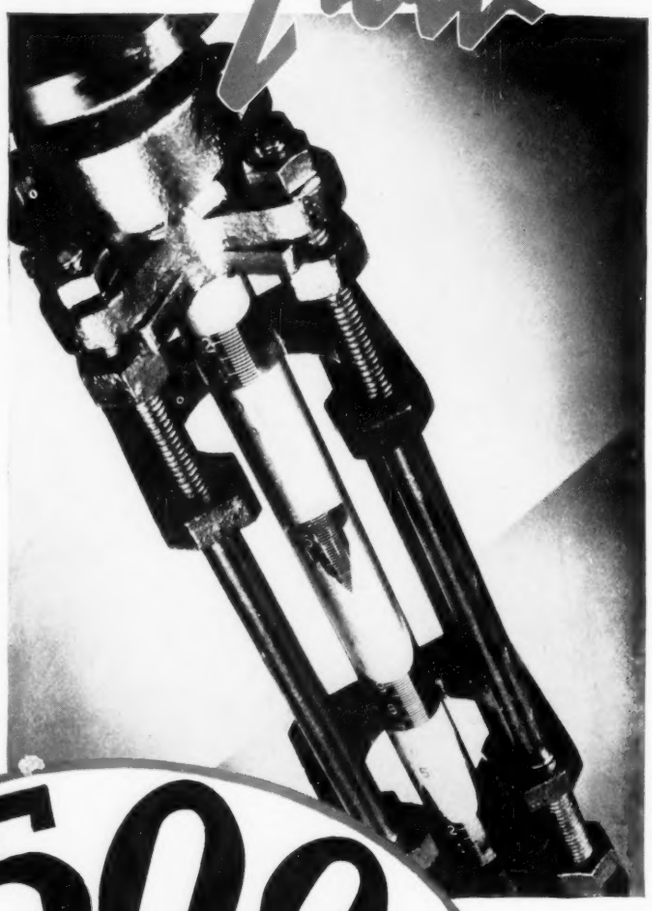

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WHAT INSTRUMENTS DO FOR

The Chemical Industries

By M. G. MASTIN
Chief Chemist, Westvaco Chlorine Products Corp.,
Newark, California

MODERN industrial chemical processes differ most from those used half a century ago in the following ways:

1—Much better knowledge of how a step is proceeding at any given moment, and better means of control.

2—More continuous processes instead of batch methods.

3—Many processes considered commonplace today were impossible only a relatively short time ago.

4—Greater output per man together with much improved working conditions.

Credit for such improvements may be assigned to three things:

1—Our great advance in chemical knowledge, in general.

2—Far better materials of construction.

3—Instrumentation.

I find it extremely difficult to visualize a chemical industry operating today without instrumentation as it must have done in the past century. Most processes were carried out at atmospheric pressure, although temperatures nearly as high as those used today were not uncommon. Thermometers had a limited range and were supplemented by the eyes of experienced workmen who read temperature from the "color" of their furnaces. The progress of many reactions was judged by the appearance of the evolved gases, as in the Bessemer converter, and the smoke from the stack of a boiler room. The only "recorders" must have been the log-books in which were entered the operators' observations.

Today, the use of indicating, recording and controlling instruments at any point where a measurement is of any value is so common that for a chemical plant to be without an instrument department is the exception rather than the rule, to say nothing of the reflection on the management. The development of thermometers other than those of the mercury-in-glass type such as the gas- and mercury-filled mechanical thermometers and the various thermocouples pointed the way to the addition of recording devices, and it was then only a short step to make the recorded temperature, through the instrument, actuate valves and other apsmoke-recorders on stacks and for ringing alarms when paratus in such a way as to control itself. Such steps have proceeded throughout the entire range of variables until practically every step in a chemical plant is, or can be, under instrumental care, depending only on the ingenuity of those charged with this responsibility.

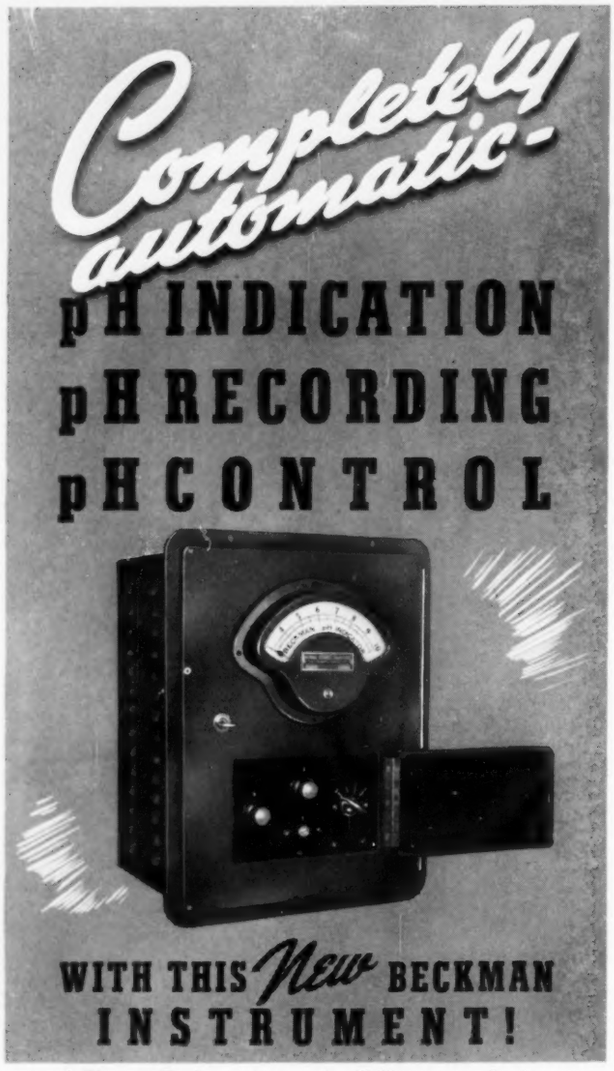
Modern materials of construction, which enable us to carry on many reactions at high temperatures and/or high pressures not permissible a generation ago, are to a large extent available only because instrumentation and consequent closer control in manufacture made them possible. In turn, newer and better materials used in instrument manufacture continue to broaden the field of application for instrumentation. Large forged vessels of special steels for the synthesis of ammonia and for the cracking of oils and gases and for other pressure reactions would be extremely difficult, if not impossible, to produce satisfactorily without suitable instruments because of the great care necessary in their heat treatment and final testing. The various stainless steels, aluminum alloys of the duralumin type, and beryllium copper—among a host of other alloys—owe their peculiar properties of hardness, or tensile strength, or machinability to the accuracy with which their various heat treatments are conducted. Many of the same metals and alloys make instruments more versatile and extend their uses. Stainless steel gas-filled thermometer bulbs for use at high temperatures and in corrosive surroundings, special alloy thermocouples and special highly-magnetic alloys may be mentioned as examples.

As in many other industries, chemical plants use many indicating and recording thermometers, pyrometers, pressure gages, flowmeters of all types, scales, feeders, and all the usual instruments. Chemists also enjoy putting instruments to work at making their analyses for them, and in some instances let their instruments control processes through the analyses thus made. Devices for measuring and recording pH and conductivity have wide application, and nearly every boiler-room operator is familiar with the CO_2 recorders which help him control his fires. Humidity recorders are finding wide use now that air-conditioning is playing such a large part in many plants where humidity must be controlled. Photoelectric tubes and cells are used as smoke-recorders on stacks and for ringing alarms when fluid flows in pipe-lines become cloudy instead of clear, as well as their more familiar use for counting objects or for sorting by color. At least one process is known where instrumentation has complete control except for emptying a tank after the batch is completed. In this case a solution of a salt is oxidized by air being blown through it under rather narrow and changing pH limits. The control does a much better job than was ever done by hand operation.

In chemical work it often is necessary to maintain two or more flows in definite chemical proportion to each other. The flows may be all fluid or they may be both fluid and solid. The chemical composition of the individual flows may vary or remain constant. Some one property of each flow is chosen for control, and suitable instruments measure this property and take charge of the proportioning. For example, two flows of different specific gravities are blended to produce a mixture of a constant desired gravity; or it may be that temperature is chosen instead. Sometimes solutions are made alkaline or acidified to a definite pH by such controls. If no other property can be utilized, the weights or volumes of the different flows are proportioned to each other. Some of the above applications are simple, and some involve considerable complications with respect to time lag in the reactions dealt with, which necessitates the use of more or less elaborate anticipatory devices so that an excess of first one reagent and then the other is avoided.

The controls commanded by the measuring instruments may be, in the simpler cases, only solenoid valves of the go or no go type, usually placed in a by-pass around a hand-controlled valve. More accuracy is obtained by reversing-motor-operated valves which modulate the flow over a wide range, or by the familiar air-operated diaphragm valves which today can be positioned with great exactness. Sometimes two or more valves of different sizes are operated in parallel, the finer adjustments being obtained by the smallest valve. Another form of diaphragm is the familiar bellows on the simpler forms of temperature controllers.

Continuous processes in the chemical industry represent, in many cases, all the advantages of the straight-line assembly plants of the automotive industry. Their success depends mainly on the ability of the operators to control each step within the necessary limits. Sometimes the control lies in the design of the apparatus at that point: *e.g.*, reaction time is obtained by providing sufficient storage volume, or a large filter replaces a smaller one as the simplest means of overcoming a difficult filter operation due to variable crystal characteristics. More often, closer control of each step is the correct solution, because of better reaction efficiency or because a step can be carried out in smaller equipment, or because a better and more uniform product can be made. Instruments then become the guardians who



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watch over the necessary control points and who are responsible for the success of the operation as a whole. Flows are adjusted and maintained; temperatures and pressures held within necessary limits; reactions, filtration, distillation, evaporation, crystallization, drying—all are under instrumental control. The uninitiated might wonder that any human operators would be required at all. The fact is that no instrument is perfect all the time and that men must still be present to supervise and service the instruments and keep a watchful eye on things in general. Nevertheless the mechanical operator makes possible a degree of perfection that would be difficult if not impossible to the human operator unassisted.

There are still many chemical products made by batch methods rather than by continuous processes. This is usually because production is not large, or because the quality of the product is such that the degree of supervision necessary is more than can be imposed on a continuous system. Many fine chemicals and medicinal chemicals are batched for this reason, and because a batch can be held until final analyses show the quality to be that desired. The very fact that in this type of operation quality must be kept high, necessiates instrumental control of process steps.

Although perhaps not classed strictly as a chemical industry, the manufacture of modern refractories does involve a great many chemical reactions, and the degree of instrumentation here employed has largely been responsible for the high-quality, low-cost products now available. Process steps vary from crushing and grinding through reaction, classification, filtration, mixing, calcination, back to various sizing operations. Production is large, continuous, and subject to a high degree of instrumental control, especially in the reaction and calcination steps. Modern tunnel kilns and rotary kilns are practically self-operating. Fires are now controlled by pyrometer controllers operated either by thermocouples or by radiation pyrometers at the higher temperatures. Fuel efficiencies are maintained by automatic draft controls, and the products themselves reach a degree of uniformity impossible by manual control alone. Many refractories are burned at temperatures just below or at their incipient softening point, and temperatures must be controlled within very narrow limits. Furthermore the lives of the refractory linings of the furnaces used for their burning are either short or long depending largely on the temperatures maintained.

Instrumentation also plays a considerable part in modern plant expansion. Not only do suitable instruments become a part of new plant design, but additional instruments are relied upon by the breaking-in personnel to aid them in controlling various steps where uncertainties in detail have existed. Such procedures help to remove the headaches from the early stages of a new operation.

And of course the plant laboratories possess their share of instruments. New balances without fractional weights, colorimetric and electrical pH instruments, conductivity apparatus, titrating apparatus involving an "eye" that blinks when the endpoint is reached, color analyzers utilizing the precise photocell instead of the human eye, and various types of turbidimeters are among those most often used.

Perhaps the last place in a chemical plant that one would expect to find the personnel to be instrument-conscious is the accounting office. Nevertheless, present-day demand for accurate cost figures has necessitated a certain healthy curiosity on the part of the accountant as to the reliability of the quantity figures supplied him. It sometime is difficult to allocate dollar charges for materials to the various plant departments, yet unless this is done with some care, one or more products may enjoy an apparent low cost at the expense of the others. Thanks to the versatility of our instruments and the ingenuity of those employing them, accurate figures may now be obtained, and it is pleasing to note that the accountant is very much alive to this situation. The older idea that "all the dollars come from the same pocket" and that all that matters is to make the books balance no longer prevails. Chemical plant cost accounting used to be defined by certain sceptics as "an exact science based on a multitude of unjustifiable assumptions," but proper instrumentation has already provided the remedy.

Fig. 1. Centralized test board for large cities.

WHAT INSTRUMENTS DO FOR

The Communications Industry

By F. H. BEST
Transmission Maintenance Engineer, Bell Telephone Laboratories

TO furnish telephone service of present-day quality, careful maintenance of the circuits is required. This in turn is based on electrical tests made both when trouble appears and as a matter of routine to anticipate trouble. A large number of instruments are used for this work, so that the Bell System is probably the largest customer of the electrical instrument industry. Both d-c. and a-c. measurements are made, the latter covering a frequency range from as low as 4 cycles up to short-wave radio measurements. Testing is done by the regular telephone maintenance forces who are specially trained for their work. As with other activities in the telephone industry, the testing work is specialized, as it would be almost impossible for anyone to develop proficiency in the operation of such a great diversity of instruments.

In the local plant the maintenance of the office equipment and the location of faults in the cable conductors is under the supervision of the wire chief. Much of the work is done at a testboard equipped with a high-resistance voltmeter and a Wheatstone bridge (Fig. 1). The voltmeter is used for insulation measurements and as an aid in locating certain troubles. The Wheatstone bridge is of the conventional type used for making loop and Varley measurements and is one of the principal means used in locating crosses or grounds in conductors. In the larger cities where there are many central offices, it has been found advantageous to do most of the trouble locating from one large centrally-located testboard, the testing in the other offices being limited to maintenance of the office equipment.

In addition to the instruments at the testboard each of the larger offices is provided with a number of specialized testing sets for locating troubles in the office equipment and for making routine tests to determine that all of the office equipment is functioning satisfactorily. One of the simpler of these sets contains slide-wire resistances and a milliammeter; it is connected in series with the winding of the relay under test to determine that the latter operates and releases on the specified currents. A more complicated set is that found in the larger dial service areas, by which a repairman at a subscriber's telephone can get a check on the speed of rotation of the dial by dialing a certain code number and then dialing "0."

In the toll and long-distance plant, testboards are more extensive and contain, in addition to voltmeters and bridges, many accurate devices for measuring the transmission performance of the circuits.

Since most of the long-distance circuits now contain telephone repeaters and other vacuum-tube equipment, it is the general practice to make maintenance tests on circuit elements. Intervals between tests have been set, as the result of studies, so that failures during service are rare. One of the most frequently made tests is the measurement of the net transmission loss of the circuit between switchboards as this gives a quick check on the performance of the complete circuit. This measurement is made with "transmission measuring sets" of which a number of types are in use. The standard testing power of 1 milliwatt at 1000 cycles is supplied to one end of the telephone circuit and the power received at the other end is measured. The ratio between these powers, expressed in decibels, is a measure of the transmission loss or gain in the circuit. The received power ranges from 0.1 milliwatt to one microwatt. Sensitive instruments must be used, or the power amplified before measuring it. D-c. instruments being the more sensitive, it is the practice to rectify the weak a-c. by means of vacuum tubes or copper-oxide rectifiers, and employ d-c. instruments. The standard testing frequency of 1000 cycles used for routine transmission testing in both the local and toll plant can be transmitted around the offices through switchboards and wiring without excessive losses and without interference with other circuits, so that great flexibility is possible in using it, and instruments can be made to fit in with the test boards from which other testing work is done.

Testing power is supplied by various generators which may be vacuum-tube oscillators or inductor alternators. A generator now commonly employed operates from commercial 60-cycle power and supplies the standard testing power of one milliwatt to one or more points. It can be used as a portable device. A variable frequency oscillator of the type used at a test board for measurements in the range from 20 to 10,000 cycles is shown in Fig. 2. To sweep this wide range by a single control without operation of switching keys would be impracticable for the ordinary resonant-circuit oscillator so recourse was had to the heterodyne principle. The single control adjusts the frequency of a tuned circuit to any value in the range about 93,000 to 103,000 cycles; this frequency is modulated with a fixed frequency of 103,000 cycles and the difference frequency is drawn off through a low-pass electrical filter. Power from one to more than a hundred milliwatts can be drawn from one of these oscillators; the actual amount applied to the circuit

Fig. 2. Transmission test board used for long-distance circuits.

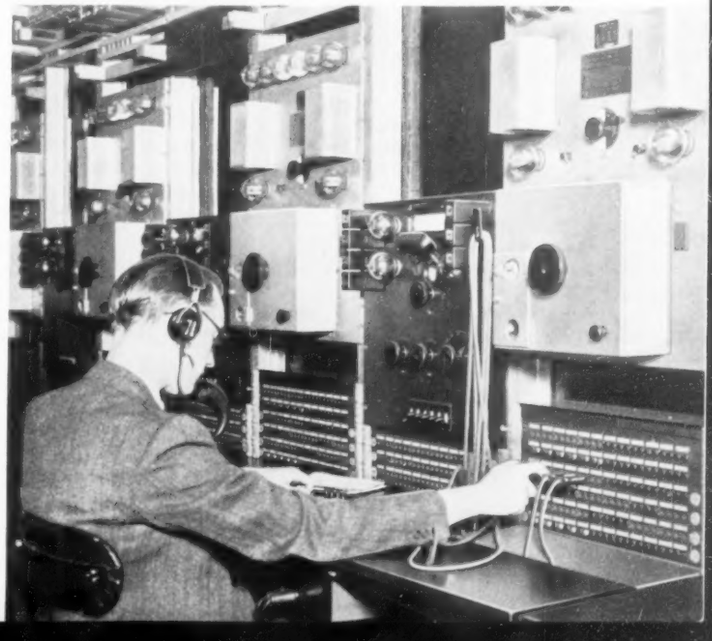


FIG. 4

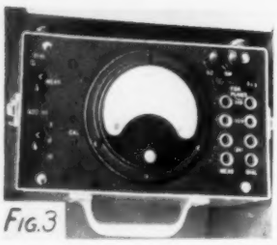


FIG. 3

Fig. 3. Portable transmission measuring set; Fig. 4. Toll test board, showing projection type meter; Fig. 5. Transmission recording system; Fig. 6. Thermocouple type transmission measuring set used for high-frequency testing; Fig. 7. Portable set for measuring noise on telephone circuits.

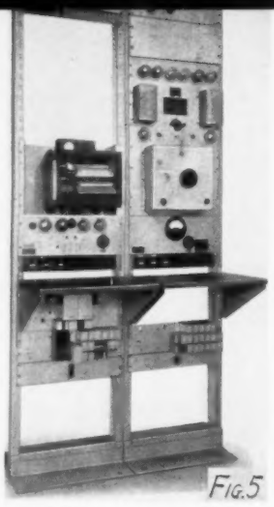


FIG. 5

FIG. 6

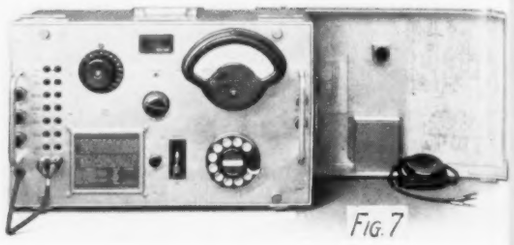


FIG. 7

under test is measured by the transmission measuring set shown to the right of the oscillator in Fig. 2.

The received current is measured with transmission measuring sets which may be of the simple copper-oxide rectifier meter type shown in Fig. 3 which has a measuring range of 20 db and is entirely portable, or it may be made by larger and more precise measuring sets containing vacuum tubes such as the one shown in Fig. 2. This latter type is not portable and it is necessary to connect the circuit to be tested by means of special testing trunks.

The latest arrangement for toll offices uses direct-reading db meters—either of the conventional type or of the projection type (Fig. 4) with which one set of testing apparatus is adequate for a large test board. For the smaller boards, the conventional type is satisfactory.

All are specially designed to give uniform db divisions. With the conventional type, non-uniform divisions would result, some much larger than necessary and others too small to be read easily. By designing the pole face of the meter so that the air gap through which the moving coil rotates is not uniform, the db divisions can be made approximately uniform over a range as great as 15 or 20 db. The projection meter illustrated is of this construction. Transmission measurements are now made as easily as measurements of voltage, the operation of connecting the receiving end of a circuit to the measuring instrument causing the pointer of the meter to indicate the net loss of the circuit directly without manipulating dials.

The projection meter, which has only recently come into general use, has been found advantageous for certain kinds of work. It uses a conventional moving-coil type of movement and can be made to have sensitivities for current and voltage similar to ordinary instruments. The scale can be easily projected to a length of 10 or 20 feet and is visible over a large area. It is unique in that there is no parallax, the same readings being obtained by observers viewing the projected image from different angles. It can be observed for long periods without eye-strain.

In addition to these routine measurements of the 1000-cycle net loss of complete toll circuits, it also is occasionally necessary to make measurements over the range of frequencies transmitted by the circuit. The same transmission measuring sets are used for this purpose as for 1000~ measurements. Where a large number of these measurements are to be made, considerable time can be saved by the use of automatic recording arrangements, such as the one shown in Fig. 5: An oscillator at one end of the line supplies testing power whose frequency is changed continuously by a synchronous motor. At the receiving end, the recorder chart is advanced by a synchronous motor. A tuned circuit responds strongly to one particular frequency, thereby energizing a magnet which makes a mark on the paper. This mark is used to align the record with the scale of frequency.

Recorders are of value also in making tests of the transmission stability of a circuit. For this type of test, the frequency of the oscillator at the sending end of the circuit is fixed, and the recorder plots continuously the transmission loss at that frequency. The location of intermittent troubles is aided by this type of measurement.

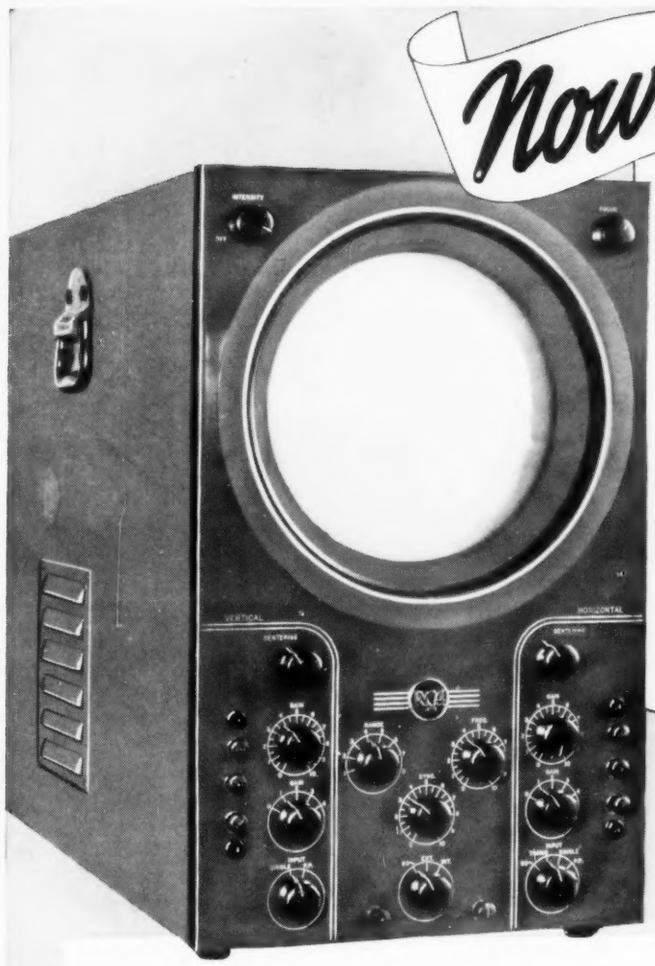
The higher frequencies used with the carrier type of toll circuits cannot be handled in as simple a manner as 1000-cycle current, and different arrangements are therefore required. The measuring instruments must be taken directly to the apparatus to be tested, trunks of any material length being impractical. The high accuracy required in maintenance measurements makes it necessary generally to use thermocouple type instruments as the characteristics of amplifiers are not easily made flat enough over the extensive frequency range used in testing. A portable device of the type commonly used in carrier system maintenance is shown in Fig. 6.

Measurements are also made of impedance and capacitance, special bridges being used for this purpose. When frequencies above the audible range are measured with bridges, demodulators are required.

Measurements of the noise on telephone circuits are also commonly made. Fig. 7 is a portable set which can be used for a large variety of noise measurements. The transmission measuring arrangements shown in Fig. 4 may also be used for measuring noise, a noise-measuring amplifier being substituted for the transmission-measuring amplifier. Since the disturbing effect of noise on telephone conversations is a function of frequency, a network is included which makes the instrument response proportional to that effect rather than to the electrical energy.

The newer types of circuits require a number of tests on sections of the circuit when they are being initially installed. These tests are made to prevent crosstalk between carrier systems or between channels in the same system and are largely balance tests made during the adjustment of apparatus which neutralizes unbalances in the circuits. A number of complex, manually-operated and automatic measuring instruments are used in this work.

In addition to the instruments described, which are for the electrical maintenance over existing circuits, there is a wide variety of instruments used in construction. Among these may be mentioned the tone generator and associated amplifier for identifying cable pairs; capacity unbalance sets, with which is measured the capacity-to-ground of the two sides of a phantom circuit in cable; and a great variety of complicated bridges for use in setting up the new high frequency circuits. Construction and maintenance of outside plant requires many instruments for mechanical tests such as pressure gages for gas-filled cables; dynomometers for measuring strand tensions; thermometers for solder and paraffin. In the traffic department, which is responsible for the handling of calls, instrumentation is confined to various kinds of counters, generally electrically operated by push-buttons in the switchboard or by the dial telephone mechanisms. Calculagraphs are extensively used for timing toll calls, and stop watches are employed for special studies. On certain circuits, where apparatus presents one call after another to the operator, a meter indicates the number of calls awaiting attention, and so apprises the supervisor of the necessity of cutting-in an additional operator's position.



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Depth . . . . 25 inches
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WHAT INSTRUMENTS DO FOR

The Food Industries

By L. G. WEINER
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ALTHOUGH canned foods were introduced about 130 years ago when Nicolas Appert, a Parisian confectioner, invented the "Art of Preserving," it has been only within the last two or three decades that the canning industry has advanced from rule-of-thumb procedures to scientifically controlled methods. Chemists, physicists, bacteriologists and mathematicians both within and outside the industry have contributed to this scientific progress with the result that precision instruments have largely eliminated the errors of human judgment.

Since an exhaustive discussion of the numerous instruments used by the canning industry with their ramified applications in the field of canned foods (which include vegetables, fruits, meat and marine products, as well as carbonated and alcoholic beverages) is beyond the scope of this article, their general use may be considered under two main groupings: instruments used in controlling the canning procedures, and instruments used in inspecting the product after canning or in advancing canning technology.

I. CONTROL INSTRUMENTATION

Raw Material

Instrumentation first finds application in the control of the raw material. Citrus growers determine proper canning maturity by expressing the juice of representative fruits and testing for their soluble solids content by means of a Brix or Balling hydrometer. Evaporated milk packers test raw milk with a hydrometer or a centrifuge in determining the quality and price to be paid to the producer on the basis of its specific gravity and volumetric cream content. Recently, pea packers have been provided with an instrument known as the Tenderometer, which indicates mechanically the relative tenderness of different lots of vined peas and their probable canning quality. The scale or balance is employed by packers of tomato products who purchase tomatoes on the U.S. Grade basis in determining the weight-percentage ratio of prime, choice and cull fruit of a representative sample at the receiving platform.

Sorting devices employing photocells are used at some storage elevators in sorting dry beans used by the packer for pork and bean products to remove stones, cracked and insect-damaged beans, and other extraneous material.

Speed indicators find a place in raw material control when threshing or vining peas and green lima beans. The use of indicating or recording tachometers assures capacity operation of the viners and serves to indicate either slow speeds that cause low yields, or excessive speeds that cause mechanical damage and impair the quality of the peas.

During the last year, X-ray equipment fitted to endless-belt conveyors has found application in locating subcutaneous areas of dry rot in beets and hollow centers in potatoes. It is not unreasonable to predict that further exploitation of photocells and X-ray equipment will provide additional means of governing the quality of the raw material used for canning purposes.

Preparation

One of the canner's most valuable assets is an abundant source of potable water with which to wash, soak, scald, convey and brine the product to be canned. The acidity or alkalinity of the water used for canning purposes, as well as for boiler feed water, is of interest with regard to effects on the canned product or corrosion of equipment. These characteristics are determined by either colorimetric or electrometric pH instruments. Flow meters and liquid-level recorders and controllers assist the canner in determining the amount of water used for specific operations and in anticipating and providing for peak loads when constant pressure and ample water supply are important. Booster pumps fitted with pressure gages and automatic control devices are used in lines supplying water to spray washers where high orifice pressures are required to flush field dirt and grit from the surfaces of tomatoes, spinach, asparagus and other vegetables.

Blanching is a phase of the canning procedure that requires close control for the maintenance of quality in the finished product. This operation is performed in either hot water (160 to 210°F., heated by direct steam injection) or in steam at atmospheric pressures. Based on past experience, the canner is acquainted with the optimum blanching schedule that will be most effective for the variety, maturity and the specific product involved. Care must be taken to avoid over-blanching which will result in a soft, mushy product and a turbid brine, or under-blanching wherein the benefits of the procedure are not obtained and the product is too firm to facilitate its proper filling into containers. Fluctuating loads of a cold product entering the blanching equipment necessitate the use of automatic controllers. The air-operated controllers may be of the indicating type or of the non-indicating type in which case the controller installation is augmented with indicatng hermometers. Each blanching installation requires special consideration: in the case of tubular blanchers where the product is being propelled with circulating hot water, "automatic-reset" controllers are required to diminish the lag period. Temperature, however, is only one component of the blanching schedule. The length of the blanch at a controlled temperature must be considered and tachometers are used to check pulley speeds and permit proper setting of variable-speed driving mechanisms to govern the time element of the blanch. Frequent changes in the length of the blanch, depending upon the maturity of the product, require the use of timing devices.

Many pea canners employ quality graders to maintain uniform tenderness of the canned product by separating the succulent and fancier peas from the more mature peas by means of their difference in buoyancy in a salt solution of a given density. Because of the dilution effect of the residual water on the surface of the washed and/or blanched peas, as well as the natural absorption of salt from the solution during the separating cycle, manual control of the density of the salt solution through frequent hydrometer readings on the specific gravity or salometer scale is impractical if not impossible. Salinity instrumentation for such an installation may consist of either float-actuated controllers and recorders, or electrical conductivity indicators and controllers. Similar instrumentation also finds use in the control of cucumber pickle, meat curing pickle, and olive curing brines.

Prior to filling the prepared and selected product into the cans, salt and sugar brines, sugar syrups and a variety of sauces must be compounded, preheated, and piped to the filling equipment. Temperature controllers installed at the brine or sauce tank of the filling equipment insure the maintenance of proper filling temperatures of these liquids.

Following the filling operation, it often is necessary to preheat or exhaust the filled and brined cans prior to hermetic closure so as to expel air from the headspace of the can, thus preventing excessive can straining during the sterilization procedure. Both hot water and atmospheric

steam exhaust boxes of the circular, rectangular or straight-line conveyor type are used in the industry. The regulation of the time-temperature relationship of the exhausting procedure is governed by variable speed drives and temperature controllers. For hot water exhaust boxes, the use of a liquid-level controller which actuates a small diaphragm valve in the drain line of a hot-water exhaust box assures the maintenance of a constant water level under varying load conditions.

When the product can be preheated to permit hot closure (160° F. or above) as in the case of cream style corn, pumpkin, tomato puree, tomato juice, fruit juices, sandwich spreads and the like, subsequent exhausting is not necessary. Maintenance of proper filling temperatures is assured by immersing the bulb of an automatic temperature controller and recorder in the product being preheated in steam jacketed kettles, batch mixers, blending tanks, tubular heaters and auxiliary holding tanks above the bowl of the filler.

Vacuum packed products such as whole grain corn, coffee, shoestring potatoes and a host of others, also require instrumentation. Bourdon tube vacuum gages or manometers are installed on the vacuum closing machines to indicate proper withdrawal of air from the sealing chamber. Barometers are consulted daily by coffee packers who are employing vacuum closure for canned coffee to make certain that the maximum vacuum is being drawn at the closing machine, depending upon the elevation of the installation and the existing atmospheric pressure. Other products such as nuts, candies, dry cereal, flours and potato chips which do not require thermal sterilization are Vitapacked or hermetically closed in the container in an atmosphere of inert gas such as carbon dioxide or nitrogen, so as to prevent staling. Gas flow to the closing equipment is controlled by high-low pressure regulators affixed to the gas cylinders to maintain proper gassing conditions without wasteful use of the gas.

Processing

Although due consideration must be given to the selection of the raw material, its preparation, proper filling and perfect hermetic closure in suitable containers, the wholesomeness of the preserved food and its fitness for human consumption depend upon proper processing or thermal sterilization to destroy microorganisms that would cause food spoilage or endanger the health of the consumer. The science of canned food sterilization has advanced to a point where it is possible to fix processes that will assure commercial sterility of the product. Because of the narrow working limits of a given process, hand control methods have been largely supplanted by thermal control instruments.

Commerical sterilization may be carried on in open vat cookers in either batchwise or continuous fashion in the case of acid products (pH 4.5 or below), while processing of the non-acid products (pH above 4.5), requires the use of pressure cookers or autoclaves known as retorts in the canning industry. When rapid transfer of heat through the product is necessary for quality maintenance, continuous or agitating type pressure cookers are also used for pressure processing some products, such as evaporated milk. Regardless of the type of processing equipment, or the range of processing temperatures, air-operated or steam pressure actuated diaphragm or spring type controllers are relied upon for accurate maintenance of the processing temperature. The controllers may be of the recording or non-recording temperature type. In some instances, recording thermometers augment the temperature controller installation so that the canner may have a graphic record of the process to which a given lot of canned goods has been subjected. The industrial or mercury-in-glass thermometer is used as a reference instrument on all processing equipment. Bourdon tube pressure or compound gages are a "*must*" instrumentation for pressure retorts to check the temperature-pressure relationship, and as a safety measure. The use of the can center temperature instrument indicates the final can center temperature attained in canned products processed in an open bath and serves to assist the canner in regulating the length of such processes.

Cooling

Prompt and thorough water cooling is an aid in preventing loss in quality and retards corrosion of the container by the more acid products. Water cooling may be conducted in the tank or retort in which the cans were processed, or the baskets of cans may be removed from the retort and conveyed through cold water in a cooling canal. When water is scarce or is expensive, the installation of flow meters and temperature controllers to govern the flow of water aids in effecting efficient cooling under the most economical conditions.

Cans larger than 4 $\frac{1}{16}$" in diameter which have been pressure processed require water cooling under pressure in the retort by means of superimposed steam or air pressure to prevent straining and buckling of the cans during the cooling cycle. Instruments, again, are brought into play, since frequent reference to the pressure gage installed on the retort assists the operator in avoiding too rapid a pressure drop while the cooling water is being admitted to the retort and allowed to escape through the overflow pipe. A pressure gage installed on the water supply line to the battery of retorts indicates the water pressure available for pressure cooling purposes.

Pressure processing and pressure cooling of larger cans may be made fully automatic through the use of automatic cycle controllers with cams driven by clock-work. With this type of installation, the steam is automatically turned on, the gradual rise of temperature and pressure and proper release of the air entrapped in the retort are all governed, and the maintenance of the required processing time and temperature assured. Upon conclusion of the process, the cycle controller turns off the steam, maintains the proper superimposed air pressure while admitting the cooling water and gradually reduces the pressure to atmospheric conditions—all in accordance with a predetermined schedule. Such instruments are quite flexible: changes in the process and cooling periods are made by resetting the cam mechanism.

II. INSPECTION AND RESEARCH INSTRUMENTATION

Quality Inspection

It is the aim of the discriminating canner to pack quality merchandise that can be sold at a profit and to avoid canning practices that will result in merchantable losses due to spoilage or failure to comply with the mandatory requirements of the Federal Food and Drug Laws. In realizing this goal, it is necessary for the packer to examine his products at frequent intervals to make certain that the manufacturing procedures are above reproach. Many canners maintain canned food inspection laboratories manned by competent technicians, who determine the grade and workmanship of each day's pack throughout the canning season. Research laboratories affiliated with the industry aid the canner in locating and correcting those practices which are detrimental to the quality and grade of the canned product.

Canned food inspection necessitates diversified instrumentation. Low- and high-power microscopes and special counting cells for comminuted products are used to detect the use of inferior raw material which, through lack of proper workmanship, may find its way into the finished product. Sensitive balances are used to make certain that the product meets the label weight declaration and that the proper ratio of solids to liquid medium exists. Bourdon tube vacuum gages fitted with gasketed piercing points are employed to measure the can vacuum which is an important consideration in predicting the storage behavior of the product. The amount of free space or headspace existing in the can is measured by means of a headspace or depth gage to determine compliance with the Federal requirements of fill. The Munsell color apparatus is employed to measure color on the basis of hue, brilliance and chroma for those canned

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WHAT INSTRUMENTS DO FOR

The Forest Product Industries

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IN the Forest Products Industries are included many varied activities requiring measurement and control, ranging from actual forestry practice through drying and preservation, extraction and destructive distillation processes, to pulping methods and the individual methods used for the various types of papers and specialties.* In this discussion we shall sketch the extent of intrumentation in several of the principal branches of the industry, leaving the details of the highly-developed techniques of power development and the unit processes such as distillation to specialists in those fields.

The extent of instrumentation in any industry increases with the return to be expected therefrom; and it therefore increases with the size and specialization of the converting plants, and with the relative costs for labor and waste.

The actual timber harvesting or cutting operations that form the basis of the whole industry have not developed instrumentation since they are largely based upon individual workmen operating on a craft basis.

In the related activities of cruising and surveying forest properties, many tool-instruments have been devised for mapping operations and for accurate measurements of sample trees. The spread of scientific forestry methods in fire prevention has led to the use of true instruments such as the Duff Hygrometer for measurement of the moisture content of the forest floor, standard meteorological instruments for weather prediction, and the use of such modern aids as aeroplanes, telephones and radio. Similar means are employed in forest propagation work together with an ingenious application of use of the photoelectric cell for actual measurements of crown density.

A broad classification of the various forms in which products of the forest come to market is outlined below:†

Class A—Piece products largely in the original form.
1. Round products such as poles, piling, posts, mine timbers, etc.
2. Shaped products such as ties.

Class B—Manufactured products of definite form, retaining the original wood structure and entailing waste in manufacture.
1. Lumber manufactured from logs into structural timbers, dimension lumber and boards and planing mill and other special products.
2. Veneers.
3. Products manufactured from bolts or from mill refuse such as billets, squares, blocks, shingles, spokes, staves, lath, boxboard, etc.

Class C—Naval stores, rosin, turpentine, etc.

Class D—Products in which the form or both the form and structure are destroyed.
1. Mechanical and chemical wood pulps, and the various types of papers, boards, and specialties.
2. Cellulose derivatives such as rayon, films, lacquers and other plastic products.
3. Extracts such as tanning agents.
4. Hydrolysis products.
5. Products of destructive distillation.

The products in Class A require relatively little processing except in the case of those items which may be treated under vacuum and pressure for the purpose of impregnation with toxic agents to retard deterioration. Soluble salts are used for the less permanent types of treatments, and creosotes obtained from destructive distillation processes are used to combat more severe service conditions. Instrumentation is employed for determination of the moisture content of the wood, and thermometers, pressure and vacuum gages and liquid-level gages are used in the production of and testing for the various degrees of penetration required.

The products listed under Class B are required to meet rigid specifications as to quality and dimensions.

It is necessary that the moisture content of wood be reduced and stabilized before the final sizing operations to minimize warping, checking, and shrinkage in use. In the past, it was universal practice to cut the logs to rough lumber and to pile and air dry it out-of-doors for long periods of time before the final processing. Two or more seasons were required, entailing tie-up of large amounts of capital. In addition there was considerable spoilage and fire loss.

Early attempts to hasten the drying by heating in dry kilns produced such an inferior product that a prejudice still exists against kiln dried wood in spite of the advances that have been made in recent years. Kiln drying is now quite generally replacing air drying in the larger operations. Successful operation under present practice depends largely upon use of carefully controlled temperature and humidity adapted precisely to each individual wood species.

Instrumentation ranges from simple temperature and humidity indicating instruments for guidance of manual control of batch-kilns, to the automatic controls used with continuous kilns to effect progressive changes in conditions at the several stages of the process.

In addition to the advantages of modern drying methods, modern sawmills are adopting air-operated controls for dog setting on their saw carriages together with similar air-operated remote controls for trimmer saws. These means have enabled speeding up of operations and reduction of waste together with savings in labor. For example, one plant reports that provision of air controls on a saw carriage reduced the crew from three men to one, and the one man remaining does a better job.

The production of veneers requires careful control of the moisture content of the wood. Instrumentation is increasing with the rapid growth of the industry and with the increasing use of the new synthetic adhesives.

The Naval stores items (Class C) are, we believe, covered in other articles. Let it suffice to say that quality and yields have been improved by technical control, guided by instrumentation.

Most of the products listed under Class D as changed in form and structure have to meet rigid quality and uniformity specifications. This fact and also the fact that the manufacturing processes involve large and centralized plants of high capital cost per unit capacity have led to extensive instrumentation.

The paper industry is the most extensive one under this classification and the pulping phase of this industry has seen its share in the application of instrumentation.

Of the pulping methods the mechanical or groundwood process is probably largest in tonnage of product per annum. This pulp finds its largest use in the cheaper newsprint and board type of product. The groundwood process is largely mechanical as the name would imply, and the large power requirements forced early application of usual power-plant control means. During the last ten or fifteen years developments in the associated paper fabrication processes have required increased control of the quality of the groundwood component. This has led to quite general adoption of automatic devices for maintenance of constant temperatures at the grinders by control of the volume of dilution water. Incidentally it has been found that this control

*Of recent years, wood in the form of wood pulp has become an important raw material in the field of rayon and other special cellulose derivatives. These latter products are beyond the scope of this present review.

†Adapted from "Forest Mensuration" by H. H. Chapman.

stabilizes conditions through the subsequent screening, riffling, and thickening operations and the stable temperature condition increases the life of the grinder stones.

Tests for consistence are made for guidance in manual control of the screening operations, and tests for freeness, or rate of drainage of water from the pulp, are used for control of the pulp grinders.

Another mechanical process of growing importance is the Masonite process whereby wet wood chips are literally exploded by sudden release of pressure. The operations of loading of the wood, admission of steam, and release of the charge are all automatically controlled by mechanisms of the cycle controller type.

Of the chemical pulping methods the sulphite pulping process has long used indicating and recording pressure gages and thermometers, and automatic pressure controls, required by reason of the comparative complexity of the process and the vital necessity of duplication of results. The use of indicating and recording means still requires that the digester cook make many delicate manual adjustments. During the past several years most of the "art and mystery" of the process has been eliminated by provision of steam flow-rate controllers and time-cycle controls for automatic control of temperature and pressure. With the successful application of forced circulation of the cooking acid through the digester charge and the introduction of external heat exchangers for supplying heat to the circulating liquor, automatic time-temperature control has been most successful in application. When supplemented by mechanical devices for uniform charging of the wood chips to the digester, the control of quality and uniformity of pulp produced is surprisingly accurate and reproducible considering that the pulping reactions involve two phases, namely, liquid and solid. And the increase in plant capacity—through higher yield per unit of wood and increase in volumetric capacity of the digester units—makes an attractive economic advantage in addition.

Time-cycle controls are occasionally used to advantage with direct-steamed digesters without forced circulation, but it often is difficult to find a representative location for the sensitive element of the temperature control.

It may be of interest to note that the earlier digester temperature instruments were of the vapor-pressure type, but that present trend is toward instruments based upon electrical principles. Either resistance thermometers or thermocouples are free from the faults which prove troublesome in the vapor-tension instruments. The electrical equipment is dependable and installation and repairs are simple and may be made by the mill electricians.

The successes of instrumentation in the critical cooking phase have led to quite general use of automatic controls and recorders in the other portions of the systems. For example, pressure and temperature recorders and controls are used in the preparation of the bisulphite acid used in the cooking process. Instruments are available for automatic gas analysis for SO_2 content, and recently one of these instruments has been adapted for automatic record and control of the sulphur burning process.

Variations in pulp consistence and rate in a pulp screening system tend to give an inferior product. There are several types of consistence regulators available for maintenance of uniform consistence conditions. The regulators in most common use require stock consistence above 3% for satisfactory service. In general, these instruments "feel" the vicosity of a pulp suspension and add varying amounts of water as required to maintain a pre-determined viscosity and consistence. Means for detection vary from that of a drag in a moving stream of pulp to various types of stirring elements. The dilution valves were formerly actuated by direct mechanical linkage, but the newer models generally use hydraulic or electrical controls. Photoelectric means are available for testing the consistence of thin stock suspensions. These instruments, depending upon changes in light transmission and reflectance, are used principally in the new mills in the Pacific Coast group. Throughout sulphite mills quite general use is now made of liquid-level recorders and controls for measurement of ingredients and prevention of waste. Increasing interest in means for reduction of stream pollution requires instrumentation such as recording weirs and automatic sampling devices for the study of the sources of wastes. It is necessary to bleach the sulphite pulp for use in the better grades of papers, and the modern multi-stage bleacheries furnish many examples of instrumentation for testing and control of proportions and process variables. Temperatures, levels, and consistence are regulated automatically, and special testing instruments are used to pre-determine the proper proportions of chlorine, alkali, and bleach liquors.

Mills producing chemical pulps by the sulphate and the soda processes have been slower in adoption of automatic cooking control but now—particularly the many new sulphate mills in Southern states—are making rapid strides.

Formerly it was difficult and costly to bleach the sulphate, or kraft pulps so that use of the product was confined to lower grade products. The process has the advantage that resinous woods may be cooked successfully. Improvements in the pulping process and bleaching methods have enabled the producers to make the better grades of papers and the increased quality requirements have forced instrumentation. The control of an alkaline cook is less complicated than that of a sulphite cook, but the recovery of chemicals in the former process is important and comprises several conversions. The steps are those of recovery of the liquors from the pulp by counter-current washing, the evaporation in conventional multi-stage evaporators, a final concentration in special evaporators, combustion of the organic matter, followed by recovery of chemicals in the smelted ash and causticizing and fortification for re-use. Usual evaporator and combustion control practices are used in the recovery process, with modifications as covered in the descriptions of new Southern mills in the recent pulp and paper literature.

The screening and bleaching operations are similar to those for sulphite pulp; similar means are used for control.

All of the chemical pulping processes require considerable laboratory testing of raw materials and products, and in some cases means have been devised for continuous automatic records and control of density, hydrogen-ion concentration and conductivity.

Conversion of pulp into paper presents many exacting problems, and the industry has been ready in adoption of automatic control. Delivery of pulp in water suspension direct from the pulp mill has been made possible by means for precise regulation of consistence and by special rate controllers or proportioning meters to supply the required blends of fibrous and non-fibrous components at the paper machines. Large savings in labor are realized by following this procedure. The necessity of control of consistence to the paper mill system is more vital than in the pulp mill because of the large effect upon refining and the close tolerances for the finished paper.

Special automatic devices for guidance of the machine clothing have been in common use for years. Instruments for indication of the weighting of wet press rolls are in quite general use and are credited with savings in machine felts and the cost of steam for drying. Similar means are used for guidance in the adjustment of supercalenders which are used to produce a gloss or finishing of the paper surface.

Elaborate mechanical and electrical means are in use for automatic regulation of the draw or relative speeds of the various sections of the paper machine to avoid breakage of the paper due to changes in sheet tension which take place as it dries. Automatic temperature control is used at several points in the process, such as the stock in the headbox, the heated air furnished to the machine and for recirculation of air from the dryer hood. Temperatures of calender rolls are maintained by automatic control of heating or cooling fluids. Photocells give warning when the sheet of paper breaks in process.

Equipment is in use for continuous record of stock freeness. A paper machine system uses many liquid level gages and controls and there are paper machines in operation where the usual headbox for control of quantity and distribution has been replaced by a system of headers with an accurate pressure control system supplanting the customary overflow headbox for hydraulic head control. Automatic means are in use for regulation of vacuum used in the suc-

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WHAT INSTRUMENTS DO FOR

The Iron and Steel Industries

By MARTIN J. CONWAY

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IN the Iron and Steel Industry we have traveled a long way since the day of hand puddling when the puddler depended on the appearance and "feel" of the ball for the quality of the iron which ultimately was formed into a locomotive boiler stay rod. Today, even the common tobacco container or soup can is originally the flat product from the modern strip mill, produced under the strict supervision of instruments which control rolling temperatures, rolling speed, descaling sprays, gage, and subsequent heat treatment. Though made by the mile daily, with a minimum of human supervision, this humble product is by far more uniform to both chemical and physical specifications than the best day's output of the best old-time puddler. Yes, we have traveled a long way in a short time—and instrumentation has been our magic carpet. Practically every type of industrial instrument manufactured serves some purpose in the industry. There are several plants having each a total of more than 500 recorders and recorder-controllers.

Starting with the iron and coal mines and limestone quarries, we find not only the more common industrial instruments, but such devices as recording tachometers which show at all times whether or not there was a proper supply of fresh air or the correct withdrawal of impure air through the main ventilating passage in the mines.

Passing on from the mines and quarries, we come to the by-product coke plant, whose operation necessitates the use of an impressive list of instruments. The nature of the work demands that most of these instruments be housed in moisture-, fume- and dust-proof cases. This fume- or moisture-proofing may vary from rubber gaskets in the sulphate department to felt gaskets in the benzol department. The ranges of some of the pressure instruments may vary from inches of mercury to millimeters or centimeters of kerosene. Temperature and flow instrumentation is correspondingly diversified.

Coming next to the blast furnace where the ore meets the products of the coal mine and limestone quarry, we again find measurement and control playing an important rôle in the fusing and cleansing of these elements to form pig iron. Among the various instrument applications in the blast furnace operations are: Hot-blast control for automatically operating the mixer blast valve to maintain uniform temperature in the hot-blast line, top gas temperature recorders, blast pressure and volume recorders, top gas pressure recorders, stock level recorders, gas pressure recorders for the dust-separating system, system water pressure recorders, gas temperature recorders for various parts of the gas cleaning system, stove gas pressure, humidity recorders for cold air, etc., all of which are fairly well standardized in form and are part of the complement of tools all modern blast furnaces must use to produce iron at uniform rate and quality, as is the practice today.

While the instruments in the by-product coke plant and blast furnace are somewhat standardized due to the similarity of the various plants in which they are used, this condition does not exist to such an extent in the steel mill because of the diversity of the products handled, the technique of the particular mill and the difference in treatment required by these products.

Margin between profit and loss being exceedingly narrow, waste, leakage, and lost time due to inefficient process operations, variable quality of products and rejections must be reduced to a minimum. In overcoming these wastes the accurate measurement and control of gases and liquids offers almost unlimited possibilities. Flowmeters of all kinds have therefore found a place in checking the quantities of gases and liquids used for the various operations—so much so that in many instances they have forcibly brought out startling facts about hidden losses and unsuspected defects in plant operations; and the time is not far distant when sufficient metering instruments, correctly applied and serviced, will become part of the plant costing system.

While the gas producer plant is slowly being supplanted by the use of other fuels in the steel industry, it is essential for economical operation that at least enough attention should be given to its instrumentation as would be given to a boiler plant using the same amount of coal daily. It was common a few years ago to see a producer gas plant using 100 tons of coal or more daily, with little more than a few indicating steam pressure gages as the sole instruments. These instruments should not be below a minimum of four, recording the gas pressure, gas temperature, blast temperature and steam pressure. Other instruments and regulators can serve accounting or control.

During the past ten years, probably no operation in the steel industry has received more attention than that accorded to the open-hearth operation and during that time the average B.t.u. consumption per ton of steel has decreased substantially 15%, partly because the saving effected in the cost of manufacture of the ingot is multiplied in the finished product and partly due to the fact that until a decade ago the open hearth had not received the instrument attention that had been given to the blast furnace. The control of the operations of the reversing valves on open hearth is considered of great importance in most steel plants, whether it takes the form of automatic reversal from time, or temperature; or merely of a recording or indicating instrument as a guide for manual control. In any case it is essential that the reversing valve be operated on schedule in order that the furnace as a unit, and the checker-work, which acts as a flywheel, in particular, may be kept in perfect balance to prevent fuel waste. This, together with stack draft control, is considered the minimum instrumentation for modern open-hearth furnace operation. To these can be added combustion control wherever it can be properly applied, together with the necessary analytical instruments to check the efficiency of the system. Draft gages at various points in the checkers and flues serve as warning devices in case of restriction due to carry-over of an excess of dust in the waste gases, which adheres to the checker work and cuts down the effective cross-sectional area of the gas passages.

Great strides have likewise been made during the past few years on the application of instruments to both regenerative and recuperative soaking pits and heating furnaces. The application of fuel rate control, temperature control, combustion control, furnace pressure control, and waste gas analysis control has done much to improve heating rates per hour per square foot of hearth area, providing the steel with the correct heat treatment during the heating operation, and cutting down metallic loss due to excessive scaling of the material being heated. This has accounted for better quality in the finished product, less metallic loss, and substantial fuel savings, together with lower furnace maintenance cost. The scale loss alone, and the consequent defects it causes, amounts to several million dollars annually. We should not pass this phase of the operation without paying tribute to the part instruments and controls have played in pointing out weaknesses in furnace design and their subsequent cure.

In the heavy rolling mills we have ammeters, wattmeters, tachometers for roll speed, fast-indicating and fast-record-

ing pyrometers for roll temperature, all to guide the operator to make his work easier, yet more efficient.

On the lighter mills, the same complement of instruments is found, with others added wherever the demand exists, and as the product from the lighter mills is usually given further heat-treatment or surface-treatment after rolling, we arrive in the departments where plus or minus a few degrees spells the difference between acceptance or rejection. Normalizing and annealing are operations which must have their temperature carefully controlled and recorded. Pickling and galvanizing are automatically controlled both for time and temperature, so much so that the weight of metal deposited on the galvanized surface can be controlled within two percent.

A strip-chart wattmeter is usually used for recording the total load of the plant—and of separate departments if the load is sufficient. This record points out the need for more detailed surveys when the efficiency of the plant begins to decrease, as shown by excess power consumption for the tonnage produced. It also shows any tendency of the different shifts to idle machinery just before meal times or change of shifts, any delay in getting machines up to speed when a new shift arrives, and other lost motion which adds to the power cost of the product.

In addition to the instruments already mentioned, a large number of optical pyrometers, indicating thermometers and pyrometers, portable pressure and vacuum gages, gas analysis outfits, etc., are used to assist operators in setting or checking their various standards of operation.

Even after the material reaches the warehouse, considerable expense may be incurred by the deterioration of the sheets and other products caused by moisture in the air. This condition is remedied by the use of psychrometric recorder-controllers regulating the warm-air supply.

So far, we have touched lightly on instrumentation in the steel industry as applied to the operations of making and shaping the steel product together with the intermediate and subsequent heat-treatment. To these must be added the scientific instruments used in the testing and research departments of the industry, where the steel of tomorrow is made. High-power microscopes, equipped for use with dark-field and polarized-light illumination, permit specimens to be examined at magnifications exceeding 500 diameters, and photomicrographs made for record and comparison. It is but a few years ago that the first helper "spooned" a sample of the metal from the open-hearth furnace bath into a small mold and, after cooling and breaking the sample, judged the approximate carbon content of the steel by the appearance of the fracture. Today, with carbon limits much narrower, these preliminary tests are made by an electric carbometer in a few seconds with amazing accuracy.

Probably no other industry runs as great a number of routine tests—both chemical and physical—as does the steel industry. The equipment value for this routine testing and research work alone amounts to substantially 5 percent of the industry's invested capital, and probably carries the greatest rate of depreciation because of continued demands for improved instruments due to the industry's own research.

We cannot ignore the fact that users and fabricators of the industry's products have contributed by "putting salt on our tail" to a point where they in turn produce articles identical in strength, appearance and performance, by the million, among which we may point to the automobile as an example. These results could not be obtained without instrumentation. Instrumentation is synonymous with progress, and it has in turn also contributed to safety, cleanliness, better working conditions, more pay per hour, and more leisure for the men employed by the industry, while, at the same time, satisfying the requirements of the steel consumer for a better product at reduced cost.

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WHAT INSTRUMENTS DO FOR

The Machinery Industries

By C. E. MACFARLANE
Westinghouse Air Brake Co., East Pittsburgh, Pa.

FROM the time that raw materials start through a modern fabricating and machinery plant until they emerge a finished product, their progress is controlled or at least registered in almost every operation by some type of instrument. Through instruments it has been possible to achieve an improvement and uniformity of product which has resulted in higher quality and performance yet lower cost, less waste and scrap yet improved usefulness, appearance and sales appeal. Through instruments many of the uncertainties of the human element have been eliminated and the safety of plant operation has been increased. Without instruments modern mass production of the many articles in common use, as well as of articles made to highest standards and precision, would be impossible.

Furnaces for heating metal for forging, whether it be steel, brass, or aluminum, are equipped with pyrometers to control or at least to measure the temperature. In addition to determining the furnace temperature it often is important to make sure that the metal itself is up to heat, and for this purpose radiation pyrometers, both indicating and controlling, are available, which sight directly on the metal.

The many heat-treating operations, through which steel and other metals are put, are almost universally controlled by instruments. These include normalizing, annealing, heating for quenching, drawing, heat aging, carburizing, nitriding and other surface-hardening treatments. As to size of parts they include anything from massive forgings to delicate tools and small articles, for which furnaces of widely varying size and type are used. They may be gas- or oil-fired or electric. While temperature is the condition most generally controlled, the period of time during which the pieces remain in the furnace is also often regulated by instruments which determine the rate of continuously-operating or the frequency of intermittently-operating conveyors. In some heat-treating processes the material must pass through two or more different temperature ranges for various periods of time and must be heated or cooled at specified rates. Such processes can be completely and efficiently controlled by instruments.

In order to prevent furnaces from overrunning their control point, which is apt to occur with ordinary on-off controls, the so-called proportioning control instruments have been developed. They anticipate the setting point and throttle down the heat input as this point is approached. Another method of limiting the rate of heating is the differential control, in which two thermocouples, one registering furnace temperature and the other work temperature, are connected to the same control instrument. By limiting the difference in temperature between the two the furnace is prevented from heating at a faster rate than the work, especially at the time the steel passes through the critical point. This is advantageous for hardening intricate tools and dies.

A somewhat different function of instruments in connection with furnaces is to afford protection in case of pilot lights going out. One type shuts the furnace off completely while another type re-lights the pilot.

One of the newer surface-hardening processes consists of heating the surface of the steel with induced electric current from an inductor block. The high-frequency current which is used and the period of application, which affects the depth of hardening, are accurately controlled by instruments.

In the last few years the achievement of proper furnace atmosphere to prevent scaling and decarbonization during annealing and other heat-treating operations has received much attention. Again instruments play important rôles, such as furnishing a continuous record of CO_2 content in the furnace atmosphere, controlling the atmosphere-generating equipment, etc.

In the field of welding instruments have assisted greatly in the rapid strides which have been made. In automatic arc welding machines voltmeters and ammeters indicate the electrical conditions while automatic controls are used for operating the electrode wire feeder at the correct speed. Resistance welding machines are operated through electron tubes which allow a heavy current of the correct value to flow for a definite closely-controlled time interval through the two parts to be joined. The time of current application is usually short, as short as ½ cycle. The current application may be a single operation, as in flash welding and spot welding, or it may be intermittent, as in seam or line welding. By means of the synchronous timing device a series of small overlapping spot welds are made which result in one continuous tight seam. These current timing devices have made possible the resistance welding of thin gages of metal without burning or distortion and to weld high-strength stainless steel without appreciable loss in strength or precipitation of carbides. Aluminum also is successfully welded by this method. For longer durations of the welding current various motor-operated timers are available. In heating for forge welding the furnace or metal temperature is often controlled by means of thermoelectric or radiation pyrometers.

Many of the modern machine tools are equipped with instruments, especially when a number of different operations are to be performed serially on the same machine. These machines are not group driven, but contain their own electric and hydraulic drives. The controls are now usually built into the machines so that they can be interrelated and often the same switch regulates several operations. Magnetic controls, solenoids, timing relays, limit switches, reversing switches—are all made use of. Two-speed motors are controlled to run at one speed during part of a machining operation and at a different speed during another part. When a coolant is to be used intermittently the operation of the coolant pump can be controlled together with the corresponding machining operation. Safety devices are also incorporated, such as one for shutting off the machine when the pressure rises above a certain point in the lubricating oil system, indicating a stoppage of oil flow which would damage the machine. Gages can be built into machines which read directly, without stopping the machine, the diameter of a section being turned or the length of a piece.

A unique method for accurately controlling the diameter of a piece being machined depends on the change in air pressure caused by the obstruction of an orifice. Air blows through the orifice and as the piece approaches its final diameter it obstructs the orifice more and more, or less and less—depending on the set-up. The change in air pressure thus produced affects mercury columns, actuating electric contacts which first slow down and then shut off the feed.

There is a trend now to provide machine tools with special sockets into which removable instruments and meters can be plugged to check the performance of the motors in the machines and to check the condition of the machines themselves. One set of instruments can be used for a large number of machines and valuable information about their performance, load conditions and efficiency can be obtained with a relatively small investment.

Temperature controllers are required to keep Babbitt metal at the correct temperature for pouring sound bearings. Similar instruments are used in tinning, soldering and galvanizing installations.

Tanks containing waxes and other impregnating and coating materials for treating castings, leather, etc. are

heated by means of steam, gas or electricity and they are kept at their respective temperatures by suitable controls.

As parts pass through the various shop departments it is necessary to clean or pickle them to free them from oil or scale. In these operations the temperature of the solutions is often controlled by instruments and the acidity recorded by other instruments.

The use of molded plastics has increased tremendously within recent years and again instruments play an important rôle in their manufacture. There are many different types and grades of plastics and the molded products vary considerably in size and shape. Each necessitates particular manufacturing conditions in order to obtain best results. For many parts the exact size of the charge is important, so automatic devices measure out—by volume or by weight—the correct amount to fill the mold. The trend in molding presses, similar to the trend in machine tools, has been away from group operation towards self-contained units with individual pressure systems. Some of the more intricate pieces may require an exact molding cycle involving mold temperature within a certain range, closing the mold at a definite speed, application of low pressure for a period, then high pressure for another period, and finally opening the mold again. All these functions can be effectively controlled by instruments and then combined in one process controller which automatically regulates the temperatures, pressures, time intervals and movements of the press without any attention from the operator. After one cycle is completed the press is ready to receive a new charge and repeat exactly the same cycle without the necessity of re-setting any controls.

In finishing processes which are used for appearance or prevention of corrosion, such as painting, enameling and japanning, subsequent drying or baking must be carried out at specified temperatures. These are controlled by low-range instruments of simple design.

Other parts are finished by electro-plating with nickel, chromium, cadmium or zinc. Each of these processes has its optimum voltage, current density and solution temperature for which there are electrical instruments and temperature regulators. For anodizing aluminum an automatic controller has been developed which gradually changes the voltage in accordance with an adjustable time cycle.

Some operations in machine shops involve the use of steam which is controlled for pressure and whose flow is metered. Others require cooling water or some drastic cooling, again controlled by instruments.

The transportation of parts and assemblies from one location to another is often carried out by means of conveyors operating continuously or intermittently. The movement of these conveyors can be controlled by various means. One method involves the use of photoelectric cells or tubes. When a piece is removed at the end of a conveyor line it allows a beam of light to strike the phototube which causes the conveyor to move until the next piece advances to the point where it intercepts the light beam and stops the conveyor. These electric eyes are used also for automatically counting articles and filling containers up to specified levels.

In the field of inspection instruments have found a multitude of applications and some ingenious devices have been produced. X-ray equipment is now used quite extensively to examine welded structures for defects such as porosity and oxides and for continuity of weld. Castings are checked for soundness, and articles built up from several materials can be examined to determine their relative position. Both X-ray photography and the fluoroscope are employed. The Magnaflux magnetic test is used to detect cracks and other flaws too small to be seen by the eye. For the inspection of heat-treated forgings direct-reading and motor-operated hardness testing instruments have become popular. An automatic scleroscope is equipped with photo-tubes adjustable to any minimum and maximum hardness range.

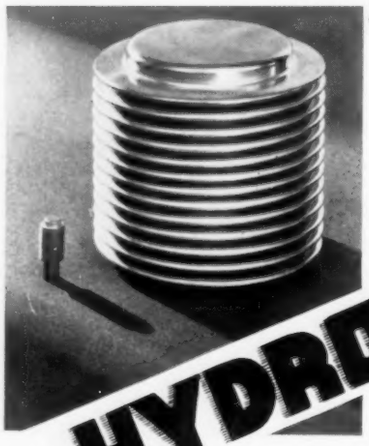
Many types of instruments are used to determine whether finished parts are of the correct size and shape. One of the most accurate tools for checking thickness and diameter is the Electrolimit gage which utilizes magnetic fields and a micro-ammeter. It indicates on a dial whether the dimension is within specified limits, set according to master standards, or how much it is over or under size. The readings are magnified up to 10,000 times and it is possible to check external and internal dimensions and angles. Another type of checking device used for piston pins and similar pieces employs a series of photo-tubes, by means of which 1500 pieces per hour are automatically measured to 0.00005" and sorted. In the same assembly, provisions for testing smoothness, hardness, and roundness can be incorporated. Intricately shaped pieces such as camshafts are gaged at 25 or more points in a series of automatic operations and those which do not pass are not only weeded out, but the location of the off dimension is marked by the instrument!

Numerous optical and even acoustic methods are utilized for inspection. Projection machines and comparators enable us to see at great magnification whether forming tools, or machined parts such as gears, are of the correct shape. Various types of gear-checking instruments have been highly perfected, including recording gages for gears.

In order to balance shafts and rotors to eliminate vibration and noise, delicate dynamic balancers are available in which electric instruments indicate how much weight should be added or subtracted and a stroboscopic lamp shows visually the location for the correction.

Laboratory testing of materials involves a large line of instruments too numerous to describe. One which has become important in recent years is the spectrograph and its accessories: the measuring microscope and the microphotometer. The spectrograph is particularly suited for determining small percentages and traces of elements.

Throughout the machinery industries instruments have become increasingly important and indispensable. As their field of application has widened and new types have been developed, their precision and sensitivity has been increased and design improved. Their speed has been stepped up, their construction is sturdier, they are less affected by unfavorable surroundings and conditions, they are more fool-proof and require less maintenance and checking.



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WHAT INSTRUMENTS DO FOR

The Non-ferrous Metallurgical Industries

By KIRKLAND MARSH

Engineer, Mech. Eng'g Div., Aluminum Co. of America, Pittsburgh, Pa.

PRODUCTION of many of the materials and goods in common use today would be too costly for commercialization were it not that modern industrial instruments have enabled close control of the manufacturing processes to be maintained, assuring a high-quality, uniform product with low scrap loss and few rejections.

Research and development work is continually improving existing and producing new processes and materials, and almost without exception these improvements and new products are the result of—or require—closer control of the variables in the manufacturing processes.

That closer control of manufacturing processes results in a more uniform product is generally admitted, but the means for obtaining such closer control is seldom credited with its full share of the results. As a chain is no better than its weakest link, so is a material no better than is represented by the properties of the poorest quality offered for sale. When closer control of manufacturing processes results in a more uniform product, the range from lowest to highest properties is reduced, with the average nearly equal to the former maximum. This extends the usefulness of the material to applications having more exacting requirements and so makes available markets not previously available to the lower-quality material.

Closer control by enabling a more uniform product to be produced is generally responsible for reduced costs for the following reasons. A more uniform product means less material rejected for failing to meet specifications. This is immediately reflected in the amount of raw materials which must be put in process, the amount of raw material on inventory, a greater production per manufacturing unit, etc.

Closer control of a process generally means a more uniform load on manufacturing equipment, eliminates not only unnecessary sudden changes in processing conditions but extremes such as high peak temperatures which hasten deterioration and boost maintenance costs.

Closer control reduces unnecessary waste of materials and energy. Consider a material that has to be heat-treated. A certain length of time must be allowed, over the minimum required, to assure that the entire mass, or all pieces of the load, have been heated to the proper temperature. The use of suitable measuring instruments to show the temperature of the load itself will permit a material reduction in this factor-of-safety overtime, which will be immediately reflected in fuel saving and increased productive capacity of existing equipment. It is common practice in many plants today to use load thermocouples to show when a load of material being heated in a furnace has actually reached the minimum required temperature. These load couples are placed directly in, or in contact with, the slowest-heating portion of the load. In some cases it is desirable to use more than one load couple but in any case the use of such equipment will result not only in a material saving in time but in assurance that all loads will be heated to the same temperature. This is particularly true in those cases in which the material must be heated to a temperature within close maximum and minimum limits, *i.e.* when the material must be heated to a certain maximum temperature only slightly higher than the required minimum. In these cases the rate of temperature rise as the load approaches the desired temperature is so low that a long time is required and the use of a load couple may result in a saving of as much as 20% of the time that the load must otherwise be left in the furnace.

Automatic temperature control permits the maximum rate of heating without danger of overheating by maintaining the furnace continuously at the maximum permissible operating temperature. It permits operating closer to the maximum temperature limits than would be safe were the control of the furnace temperature subject to human limitations.

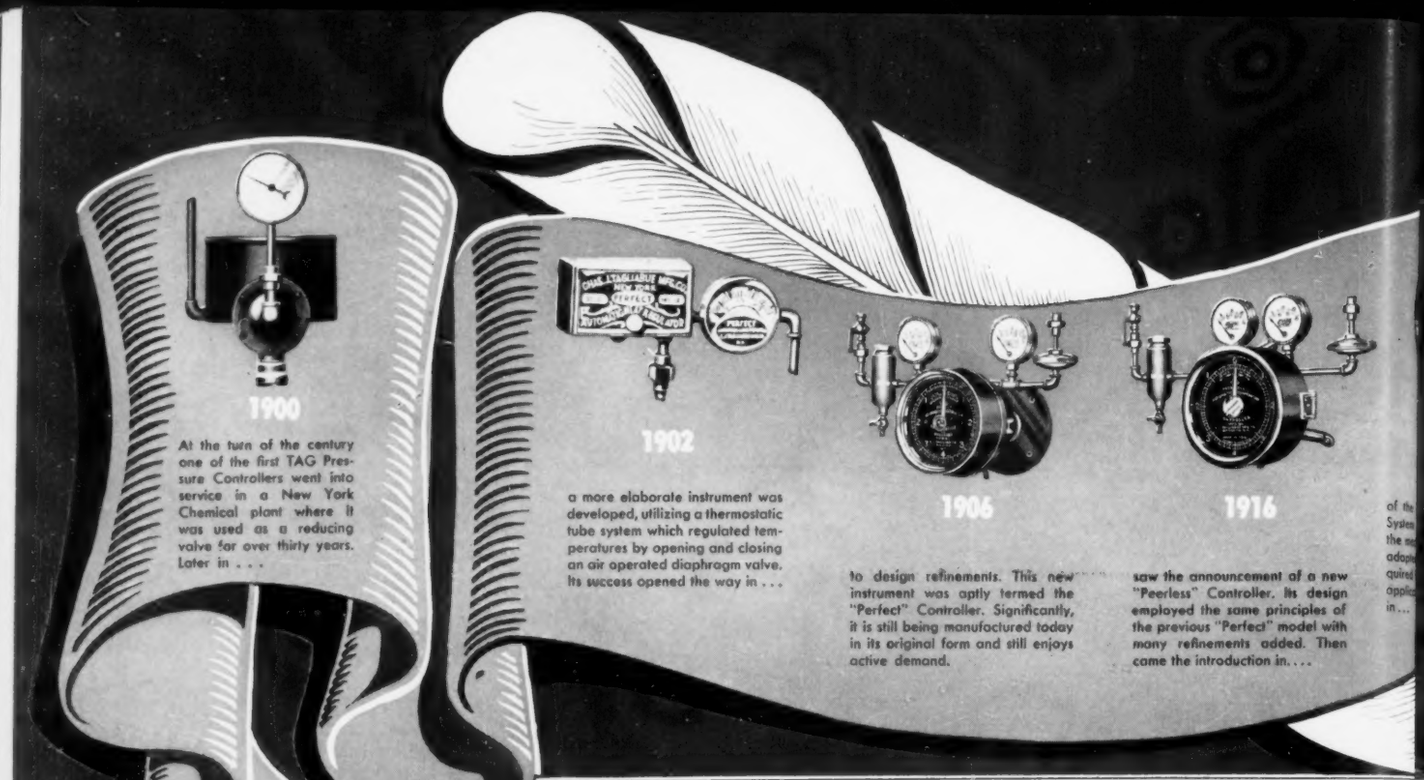
Temperature measuring equipment is generally recognized by all as being essential to the proper operation of all industrial heating furnaces but there are still many places and ways in which it can be applied to produce additional material benefits. Although automatic temperature control equipment is less familiar to many and has been less extensively adopted throughout our industries, its application to most furnaces will result in additional material benefits in the form of improved quality of product and reduced operating costs.

The automatic control of pressures and drafts has long been recognized as essential to the economical operation of boiler plants. The greatest arrays of modern industrial instruments are found today in power plants—where the benefits of such equipment can be evaluated most readily. As a consequence, the value of draft and pressure control of metallurgical furnaces is fast winning recognition. In many industries such control is regarded as essential to economical operation, particularly for furnaces where close control of atmosphere is required. And now, in consequence of interest in atmosphere control, we seem to be entering a period that may witness metallurgical-furnace instrumentation forging ahead of boiler-furnace instrumentation!

Even as the development of temperature indicating, recording, and controlling instruments has followed and continues to follow the demand of industry for such equipment, just so is the development of other industrial instruments following the demand. New and improved instruments are being brought out continuously and just as old production equipment is obsoleted by the development of new, so are old instruments obsoleted even though there are relatively few among us instrument users who recognize or will admit this fact.

Present-day competition makes it imperative that we produce the best quality at the lowest cost and the proper use of modern industrial instruments will go a long way in helping us to achieve these ends. However it requires a definite effort and considerable study to foresee, through mazes of engineering and accounting diagrams and data, the benefits to be derived from instrumentation in our own plants. The possibilities are there if we can only recognize them—as has been proven in innumerable cases. There are, of course, instances where further instrumentation cannot be justified as a sound investment; but we are wont to place in this category too many applications where actually the use of additional measuring instruments or control devices will pay good dividends.

The research and development work, referred to at the beginning of this brief outline, is itself dependent upon the use of a multitude of instruments and apparatus of all types. Vitally important to all non-ferrous metallurgical industries are the testing machines—because the discriminating users of new materials are unimpressed by qualitative descriptions such as "a tough, corrosion-resistant, highly-conductive alloy"; nor are they satisfied with the rather indefinite figures of yesteryear—such as Mohs hardness, "tensile strength," etc. They demand data which are not only quantitative but specific. Hence the A.S.T.M. and other bodies representing users and suppliers; hence also today's long—and lengthening—list of testing apparatus for determining every categorically-defined physical and chemical property from Abrasion to Weathering.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1902
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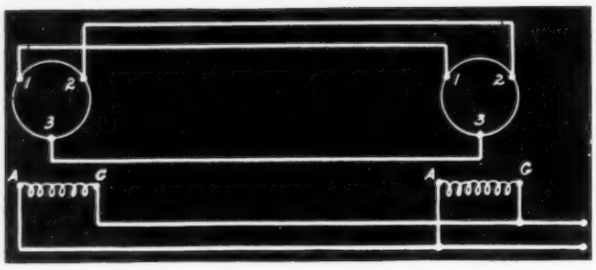

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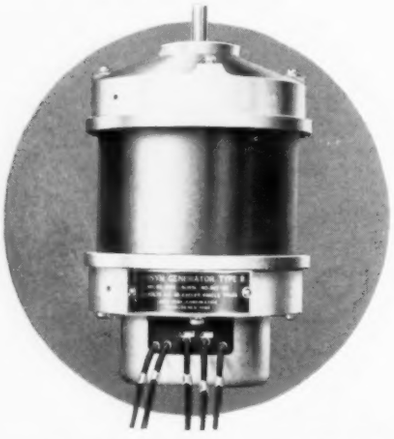

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FOREST PRODUCTS

—Concluded from page 20

tion boxes and suction rolls for water removal at the end of the sheet-forming wire.

There are several separate specialized systems for record and control of the drying operation. For example, one type controls the steam pressure in the dryers by the tension developed in the sheet by shrinkage in drying. Another general class of control tests the humidity of the film of air in contact with the moving sheet of paper and adjusts the steam supply to maintain a predetermined humidity which relates to the dryness of the paper.

A special photocell device gives a continuous record of the surface finish of a sheet of paper during super-calendering. The importance of the moisture content of paper is developing complete air-conditioning control systems.

These and other devices serve to lower costs by anticipation and correction of conditions which would otherwise cause interruption of the process and costly delays. Some of the devices serve principally to detect variations in quality which might necessitate reworking of off-standard product.

The foregoing refers to ordinary papers and light boards. Additional complications and controls are introduced when special processes such as tub sizing, calender dyeing or process coating are added.

Other minor products made from pulp include paper cups, paper plates and other containers which are usually formed on special molds from a thin pulp suspension and dried coated, and turned out as a finished product without necessity of any manual labor.

The extraction of certain woods and barks for their tanning or medicinal values is relatively simple. As an example, chestnut, hemlock, and oak wood or bark are chipped or hogged and leached for long periods for recovery of agents used in the tanning of leather. The weak liquors are concentrated in ordinary evaporators with the usual controls. The spent chestnut chips are in some cases made into chemical pulp.

A minor process for utilization of wood and wood waste in this country is that of hydrolysis to produce fermentable sugars which, in turn, are used to produce ethyl alcohol and a bulk residue containing some nutrient values and therefore used in preparation of cattle foods. This is a batch process whereby the wood wastes are digested with weak solutions of hydrochloric or sulphuric acid, neutralized, and filtered. The liquors containing the sugars are fermented and the alcohol recovered by usual still-house practice, with the usual distillation control instruments.

Destructive distillation of wood in bolt form was formerly practiced for the production of charcoal. Today it is concerned also with recovery and manufacture of the methyl alcohol, acetic acid, acetone, various esters, wood oils and tars; and the trend is toward use of small-size waste-woods and continuous mechanical units. The charcoal product is often briquetted for fuel and small amounts are used in agricultural foods. The non-condensible gaseous products are either burned as fuels or are used for production of power in internal-combustion engines. Usual distillation methods are applied for the separation of the several products obtainable from the crude pyroligenous acid, and the instrumentation is that for collection of records of pressures and temperatures, and for testing of the specific gravity of the various distillates.

It may be said, in conclusion, that the part that instrumentation has played in the Forest Products Industries has depended on the magnitude and success of the several industries and the value of the products. The paper industry is by far the most advanced with respect to the application of controls and recording devices and they are probably as diversified in character as will be found in any other industry.* To the writers it appears that the demand for higher quality products at lower cost must of necessity require continued application of adequate instrumentation as a vital phase of the manufacturing program.

*See Dr. Brabender's article, page 29, for instrument applications in the testing of finished paper products.—EDITOR.

WHAT INSTRUMENTS DO FOR

The Paper Industry

By G. J. BRABENDER

Technical Department, Marathon Paper Mills, Rothschild, Wisconsin

THE rôle played by instruments in the development of the modern paper industry closely parallels the phenomenal growth of the industry itself. Early records pertaining to the manufacture of paper in America tell us little regarding the use of instruments. A clause in the rental agreement by which Wm. Bradford transferred his interests in the earliest paper mill (in what is now the United States) to Wm. Rittenhouse states in part:

That they, the sd. Wm. and Clause Rittenhouse [son of Wm.] shall pay and deliver to sd. Wm. Bradford, his Executors or assigns or their order in Philadelphia, y^e full quantity of Seven Ream of printing paper, Two Ream of good writing paper and Two Ream of blue paper, yearly and every year during y^e sd. Term of Ten years.

This record clearly shows that the use of a ream as a measure of a certain quantity of paper was a well-established practice even in those times. Instruments for measuring the area of the sheets or at least the dimensions of the mold in which these sheets were made were undoubtedly used in the pioneer paper mills. The various grades of paper mentioned in the agreement between Bradford and Rittenhouse such as "good writing paper" and "printing paper" imply that some measurement of these qualities in the product was recognized by the users of these papers and particularly by Bradford who was a skillful printer by trade. Perhaps the quill pen and an ink made from gall nuts were the instruments used for determining the quality of the "good writing paper." Incidentally, the use of pen-and-ink *under standardized conditions* is still a satisfactory means of measuring writing quality in paper.

The first mill in central Massachusetts, built by Abijah Burbank in 1775 was considered one of the best in the country since " . . . they were able to turn out from two hundred and thirty to two hundred and fifty pounds of paper daily . . . " Thus, the use of a scale for measuring paper by weight is inferred from the description of this mill.

A special printing of the Declaration of Independence was made on paper produced in 1817 by Thomas Aines, a noted paper maker, who designed the paper to excel in quality anything made in America up to that time. "The size of sheet was twenty-six by thirty-six inches and only the finest linen rags were used. Each ream weighed one hundred and forty pounds and the price was one hundred and twenty-five dollars." Here we find a fairly complete specification for a lot of paper, including quality, ream size and weight.

A ream is still employed in the modern paper industry as a unit of measure of paper area. Instruments for measuring the weight of paper and paper-making material used in the modern industry are indispensable to its existence. They run the entire gamut of devices from the extremely sensitive microbalance to the large platform scales capable of weighing tons. The need for quality in paper and related materials has fostered the development of a host of instruments for determining physical and chemical properties. Customarily, these are classified as instruments for determining (1) strength (2) physical (3) chemical and (4) optical properties and (5) those properties which are strictly related to use requirements.

The strength properties which are commonly measured in paper are the bursting, tearing, tensile and folding strengths. The paper makers of a generation ago and their predecessors were quite expert in judging the strength qualities of a sheet by grasping a sheet with both hands, placing the tips of the thumbs together and bursting the sheet by pressure exerted by the ball of the thumb. The modern bursting strength tester, applying a similar type of pressure over a definite area and recording the pressure on a suitable gage at the moment of burst, performs a much more satisfactory service than the literal "rule of thumb" measure formerly used. Many refinements have been made on the bursting strength tester during recent years and no modern mill would attempt to make paper without it.

Tearing strength is commonly measured by determining the force required to continue a tear which has been made in the sheet under definite conditions. The force is usually that of gravity applied through a falling sector pendulum.

Tensile strength, as the name implies, is the resistance of the paper to tensile stresses. The stress may be applied mechanically and transmitted through a piston acting on a liquid-filled chamber and recorded on a pressure gage, or it may act on a pendulum to raise the latter against the force of gravity until the stressed sheet of paper is broken. Ancillary equipment is sometimes used on the pendulum type of instrument for drawing a stress-strain curve during the test and for simultaneously measuring the stretch.

Folding endurance is measured by instruments which fold the sheet through a definite angle at a uniform rate of folding and under definite tensile stress.

The physical measurement most commonly made on paper is its thickness or caliper. Here, perhaps, precision in the manufacture of instruments reaches far toward perfection. The caliper of a few years ago measured paper thickness to 0.001″ but today this same measurement is generally made to 0.0001″ and instruments graduated in such small units are quite common. A recent investigation of the compressibility of paper employed an instrument for measuring the thickness of paper to the infinitesimal value of 0.00001″.

Instruments are commonly used today for measuring the permeability of paper to air, other gases or vapors, water vapor, liquids such as water, inks, oils, and solvents, chemical solutions as well as semi-solid substances such as greases, lard and fats. These instruments are as varied in form and design as the fields in which the paper is used. A useful guide to the papermaker, air permeability, is measured by the time required for a definite quantity of air under a given pressure to pass through a certain area of sheet. Such data enable him to make adjustments on his machine that will produce a desired formation or appearance as well as strength requirements in the sheet because of a fairly close correlation in a given sheet between air permeability and these other properties.

A knowledge of the permeability of a sheet to water vapor is useful to the manufacturer of papers used as wrappers in the food, tobacco and chemical industries. This property is usually measured by subjecting the sheet to controlled but different temperature and humidity conditions on its opposite faces and determining the rate of transfer of water vapor through a sheet of definite area.

The rate of penetration of liquids through a sheet is of paramount importance to the printer or dealer in writing papers. Many instances can be enumerated where liquids come in contact with papers used in the food industries and hence where liquid penetration is of vital interest. Liquid penetration measuring instruments are extremely varied in design but practically all of them are rate-measuring devices. The type of liquid used, the method for determining the end-point of the test, the temperature, humidity and pressure conditions, and the area of sample tested are almost as varied as the number of permutations which could be formed from the diverse testing conditions.

Paper making has usually been considered an art rather than a science. The modern industry, however, is coming to be recognized as essentially a chemical process. Therefore it is subject to chemical analyses in practically every

phase of its operation. Such common analyses as the ash content, qualitative and quantitative determinations of mineral fillers and coatings, analyses for rosin, casein, glue, starch, sulphur, paraffin wax and acidic materials in paper are all made by well-known chemical methods using laboratory equipment and instruments designed for such purposes.

The field of usefulness of hydrogen-ion measuring instruments has been greatly extended by the development of the glass electrode and electrometers having vacuum-tube amplifying systems for measuring extremely small voltages. The paper industry has taken advantage of these new devices in making pH measurements of the complex colloidal systems and waters throughout the pulp and paper making processes. These instruments have been particularly useful in studies made on the bleaching of pulps, especially pulps which are most difficult to bleach such as the product made by the sulphate cooking process. Recent announcements of the perfection of automatic sampling and recording pH instruments should further extend the usefulness of these devices in paper-making processes.

An instrument of vast utility in paper-making control is the microscope. Its use in the analysis and identification of fillers, dirt specks, and particularly in fiber identification work makes it essential for control.

Instruments for the measurement of the optical characteristics of paper have played a prominent rôle in recent years. Devices for the measurement of opacity, transparency, gloss, formation, reflectance and transmittance all have been developed within the past few years and are finding an increasing usefulness in paper making. All of these devices are designed on the principle of measuring or comparing the energy from a light source by a photoelectric cell located in a system composed of light source, paper sample, and photo-sensitive cell. The lens and filter systems, the geometry with respect to the light source and the photocell location or movement of the paper sample in the system depend upon the particular property being measured. For example, in one type of reflection meter, the light from the source strikes the sample at an angle of 45° and the reflected light is measured by a photocell viewing the sample at an angle of 90°. Suitable filters are interposed between the cell and the sample to measure the reflected light energy at a given effective wave-length. The ratio between the reflected energy of the sample and that of a near perfect white body at a certain wave-length is a measure of the reflectance of the sample at that wave-length. This property has found increasing usefulness in measuring whiteness of papers and in the control of the bleaching process in pulp making.

The reflectance meter just described is essentially an abridged spectrophotometer. The recording spectrophotometer is an instrument for accurate color specification. It is capable of automatically drawing, in about three minutes, an accurate reflectance curve over the entire visible spectrum for paper samples or other materials. The reflectance curve produced by this instrument gives an absolute measure of color under any conditions of illumination and it can be used for color matching where the older and less accurate methods are unsuitable.

Finally, the manifold uses of the photoelectric cell as the sensitive element in devices useful in paper making must be recognized. Instruments for guiding sheets or webs of paper, tension controlling devices, solution and fibrous materials concentration controls and regulators, tell-tale, recording, sorting, inspecting, and classifying machines of every description utilize photo-sensitive devices.

Thus it can be readily appreciated that measuring and controlling instruments have played an important part in the development of the pulp and paper industry. The bringing of the art of paper making from the hand process and rule-of-thumb methods employed by the Chinese centuries ago, to the science of manufacturing an indispensable commodity at machine speeds up to 1500 feet per minute and in widths up to 300 inches is progress indeed. Certainly this could never have been accomplished without the valuable help of instruments.

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WHAT INSTRUMENTS DO FOR

The Petroleum Industry

By WILLIAM K. McCOY
Instrument Engineer, Gulf Oil Corporation, Pittsburgh, Pa.

IN the last twenty years the oil industry has made tremendous progress. Finished products have been immeasurably improved, yields greatly increased, losses greatly reduced, and the percentage of time that manufacturing units are in actual operation greatly increased.

The instrument (by instrument we mean all indicating, recording and controlling equipment) has played and is playing an important part. Nearly every operation which takes place in a manufacturing unit at the present time is either automatically controlled by an instrument, or an instrument furnishes the operator with the necessary information to control it properly. In addition, instruments have been responsible for much of the present development which is visible in our modern units.

In general, instruments have become the guiding hand of the industry. Refiners have learned to measure, record, and control with them, and to depend on them to furnish necessary information for future developments. They have also made it much safer and easier for the operator.

In the succeeding paragraphs it is our intention to discuss the various general classes of instrumentation and their particular application to the oil industry.

Temperature Measurement

Inasmuch as oil refining is essentially a thermal process, the indicating, recording and control of temperature has received the greatest amount of attention. The industry has seen a tremendous development in this phase since the still operator would spit on the transfer line and time the evaporation to determine its temperature, to our present potentiometer pyrometer systems where the error is not more than 0.2% to 0.3% of the total chart range. Much of the present-day equipment is operated with such close temperature control that variations of as much as five degrees in one thousand, at any point in the process, will seriously affect the yields or shut down the unit before one-half the usual time of the run has expired.

It is because oil refining does require such close measurement of temperature that the oil industry, during the last eight years, has come to use the potentiometer pyrometer almost exclusively. This instrument, in either the indicating or recording type, has the maximum accuracy available; it has the widest scale and greatest flexibility; it is practically unaffected by overranging; it has the ability to indicate or record the temperatures of a relatively large number of points; it is not affected by ambient temperature changes; it has been developed, fortunately, into a rugged instrument requiring a minimum amount of maintenance; and it is an exceedingly flexible unit, it being a relatively simple matter to change the range if desired.

It is not uncommon to have as many as twenty or more recording potentiometer pyrometers on one unit, recording temperatures at 80 to 100 points throughout the process. In addition to these 80 to 100 points, a second group of less important points are generally connected to an indicating pyrometer, and other temperatures are taken by industrial thermometers. This type of measurement has done more to develop our present-day processes than any other single factor, because it has furnished the greater bulk of the information.

Flow Measurement

While temperature measurement has probably contributed the most to the development of the present processes, the measurement of flow of fluids has been the major factor in the control of each process and in the determination of its ultimate yields and its practicability. Present refinery practice calls for the installation of some form of measuring device in every line leading to the unit. All the various methods, such as the gage stick in a tank, counting pump strokes, the versatile orifice meter and the highly accurate positive-displacement meter, are used.

The most numerous measurements are obtained by means of an orifice plate in the line and a differential-pressure recorder or indicator. This meter can be readily adapted to measure flows at high or low pressures, and at practically any rate of flow. Its extreme flexibility lends itself readily to the constant changing of refining processes. It also has the advantage, in the recording instrument, of showing trends in the changing flow rates of the process and in this respect performs its most valuable service. It is these records which are so much help to the operator, giving him a picture of the flow through each line for a relatively long period of time. This is the instrument which is used for all flow rates within the unit, and is used for cost accounting of most utility services: steam, gas, fuel oil, etc.

In the lines leaving a refining unit it is general practice to place some form of displacement or velocity type meter, particularly where more than one unit is running finished products to a common storage tank. These meters give reasonably accurate measurement, the positive-displacement type giving errors of not more than 0.1% to 0.2% over wide ranges of flow.

Pressure Measurement

Pressure measurement continues to play one of the major parts in the instrumentation of a refining unit. The indicating pressure gage is still the commonest instrument and probably the most frequently referred to for information. This is chiefly because it indicates changes, in most cases, before the other instruments can pick them up, and because pressures are generally the first values to be established in the starting up of a unit. The pressure recorder is used to determine the operating pressures which are among the chief considerations in deciding the length of time a still can be kept on stream. As the unit approaches the maximum operating pressures, it is also approaching the limit of time that it can remain on stream.

Level Measurement

Liquid level has played and will continue to play a major part in the operation of a refining unit. The industry is still using practically the same methods of measurement as in the last ten or more years: the gage glass, the differential-pressure types and the various types of static head gages. The good old gage glass, sometimes dolled up quite a bit to withstand high pressures, is still the favorite in this service. It is the best, most accurate, and most reliable. However, it does offer a certain amount of hazard when operated at high temperatures, as rain or water striking it will sometimes break the glass. The differential-pressure gage is probably the safest type available today, and is certainly the most flexible, its range varying from about two inches of water to several hundred, if necessary. However, this type is not too practical to use in the measurement of viscous fluids. The recording types of instruments are the most common found and are used as most other recording instruments to indicate trends.

Speed Measurement

Generally speaking, speed measurement is playing a rather minor rôle in modern refining. It is being used chiefly as a check on other types of instruments. The increasing popularity of the centrifugal pump, and the use of turbines as

a source of motive power, have made speed measurement a rather unimportant factor in processing. However, the tachometer still is to be found on most major pumping units.

Automatic Control

Our industry probably has used air-operated automatic control to a greater extent than any other industry. This phase of instrumentation has been largely responsible for the general improvement of the finished products, made possible longer hours of operation, permitted us to reduce the physical size of units per barrel of charge, and made it safer for the operators to work.

It should be mentioned here that due to the reduction of the time element or storage capacity in the units and the widely varying load conditions encountered, the petroleum industry has generally resorted to the most advanced type of control equipment. In most cases, where the control problem is of importance, the new type instruments having a secondary action, commonly called automatic reset or droop correction, are used. Frequently, this type is also used by the major oil companies in places where it is not imperatively needed, but is used because the instrument engineer is sure that in future he can use the instrument in some other point or process. This future use of an instrument has become one of the chief concerns of the oil-industry instrument engineer. Present-day development of refinery processes is much more rapid than the obsolescence of modern instruments and he must, therefore, attempt to purchase instruments which not only satisfactorily handle the job they are intended for at present but also some future operation. In some cases of control, notably flow and temperature, this type of controller is used almost exclusively.

Temperature control was the first to be applied to any major degree, and still finds wide application in such places as the control of the top temperature of a fractionating column, or controlling the amount of heat to be absorbed in a heat exchanger. At present there are used two general types of controllers: the potentiometer pyrometer type, which has made its appearance in the last few years; and the older type, using gas, vapor-tension, or mercury thermal systems. All the measuring systems, of course, actuate some form of air pilot or relay.

THE MAINTAINED in-built accuracy of Westcott orifice meters, whether for Indicating, Recording or Integrating, is embodied in: precision machining of differential gage body chambers . . . low angle of float travel . . . small angular travel of static pressure tube . . . only one movable part between mercury surface and chart record. Information is available on request.

AMERICAN METER COMPANY
METRIC METAL WORKS ERIE, PENNSYLVANIA

Flow control is becoming more and more popular and in many cases is supplanting other types of control. It is beginning to be used as a substitute for temperature control, in places such as the top of a fractionating tower, where the flow controller is used to feed a constant amount of reflux to the tower. This system can be used to great advantage where the amount of heat input to the tower is constant, resulting in more stable operation of the tower and permitting operation at higher vapor velocities. It is also supplanting the liquid-level controller in many cases, particularly where the level controlled stream is fed through heat exchangers, for regenerative heating. Its chief use, of course, is the control of discharge rates of pumps.

This type of control depends almost exclusively on the differential-pressure flowmeter as its measuring element, as the other types of metering equipment do not lend themselves readily to the application of air control relays. Another increasingly popular use of this type of control is for the mixing and blending of petroleum products, and chemicals of various types used in the purification of petroleum products. It is not uncommon to find forty or more of these controllers on any one modern unit.

Pressure control plays an important part in present-day operation. It is used to control the pressure held on the fractionating columns, the heating elements, the pumps and the steam, gas and oil pressures. It is axiomatic that no unit is stable that does not have constant pressure conditions.

Liquid level control is playing a less and less conspicuous part in present-day manufacturing processes. This is due chiefly to the fact that we still have practically the same controllers today that we had fifteen years ago. The two general types in use are the ball float type and the differential pressure type. The ball float type still has the limited float travel, while the differential type suffers from the same faults mentioned in the foregoing discussion of the liquid level recorder. Instrument companies could well afford to spend some development time on this subject. The present instruments are being used mostly for running products to the field, and for this service only in those cases where regenerative heating is not being used.

Speed control, like speed measurement, is rapidly disappearing from the picture today, being used only as a check or secondary method of control, to be used in case the regular control fails.

The development of the diaphragm-motor control valve to its present state of design has contributed more than anything else to the stability and long life of the present manufacturing units. The control valves at present are called upon to take care of wide ranges in flow and wide changes in pressure drop across the valve; and to handle extremely erosive and corrosive fluids, all of which they are doing in a highly satisfactory manner. The improvement of the valve plug, alone, from a flat disk type to the present parabolic plugs or the characterized V-port type of construction, has been the main factor in this development. An additional factor has been the tremendous improvement in the design of the diaphragm motor, with its increased power and the greatly reduced friction loads.

Another interesting recent development which will, we believe, receive wide acceptance in the industry is the application of manual-control handwheels in connection with diaphragm-motor control valves. Thereby, it is possible to manually operate these valves in case of failure of the controller or to limit the travel over which the instrument may operate the valve to any proportion of the valve stroke, and at the same time locate this proportion of the valve stroke anywhere within the normal valve travel. It is this design which is being used almost exclusively on transfer lines to maintain back pressure on heating elements, and in numerous instances such valves are being used without by-passes around them.

Equally interesting and useful are the new valve positioners or air relays, intended to eliminate all possible dead spots of these control valves. This little instrument is re-

ceiving wide application at the present time, and is particularly valuable where large amounts of energy must be absorbed by the valve, for instance, where extremely high pressure drops must be handled, and where viscous or dirty fluids must be controlled.

The development of the control valve to its present state of dependability has also made possible its remote operation from a centrally located panel. Valves are being used in this manner for emergency unloading of vessels and manufacturing units.

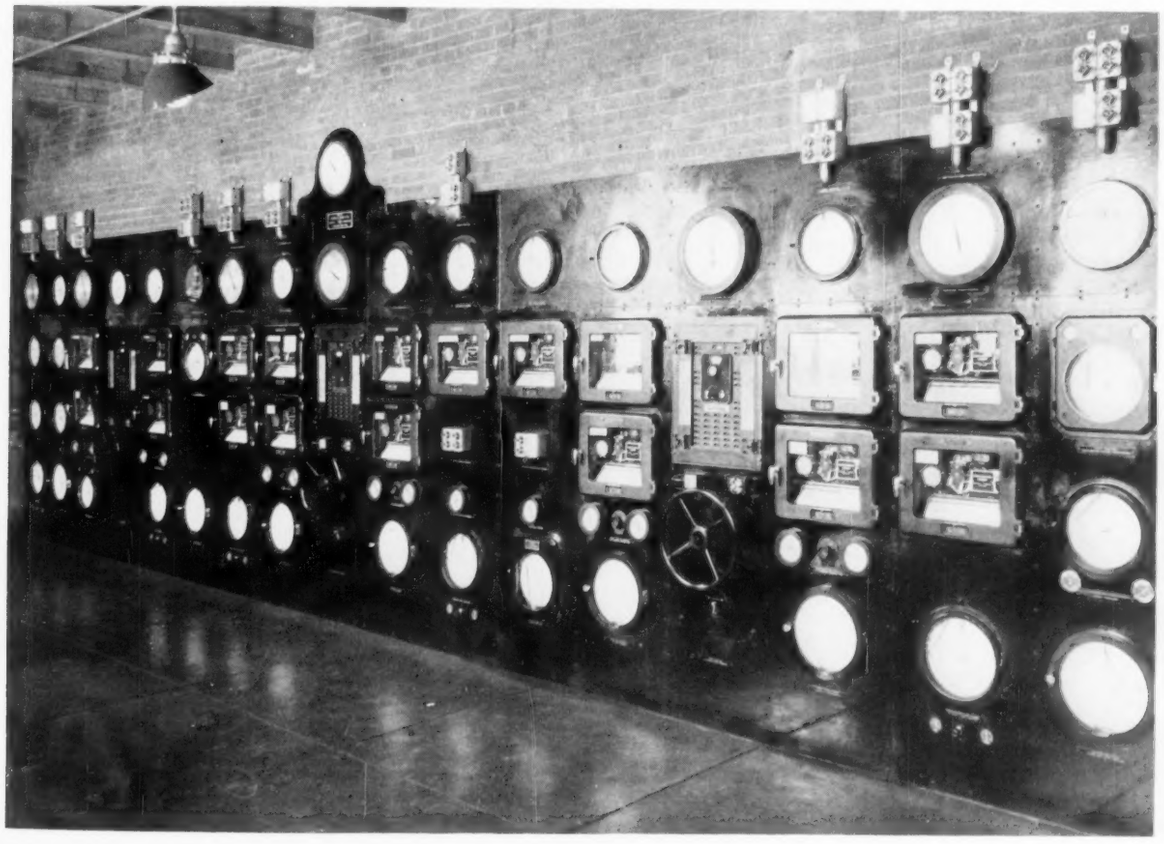
We believe that the centralization of indicating and control equipment has been more pronounced in the petroleum industry than in any other. For instance, on *all* major units there is a control board, conveniently located in an isolated room. From this board all normal operation of the process takes place. On it are assembled the temperature recorders, all essential indicating and recording pressure gages, all level recorder and indicators considered essential to the operation of the unit. Here, too, are located those flow controllers and flow meters which can be conveniently located on the board, and the temperature controllers which are used for the system. Also, the main firing controls which control the gas supplied to the heating elements. These boards, at times, reach lengths in excess of eighty feet and it is not uncommon to find as many as 150 or 160 indicating, recording and controlling instruments located on a single one. Generally speaking, one man per shift is assigned to patrol this board, observing all his instruments and firing the unit from this position. It is here that all the records are kept, and the room serves as the base of operations for the entire unit. Generally, there are one or more secondary control boards located in the pump rooms of the still, and a small board located near the heating element for emergency operation.

In the design of new equipment, more and more engineering attention is being placed upon the instruments and controllers themselves, and their proper location in the still. Control valves and orifice plates are not just stuck in the line any place, but rather the location of these is definitely planned. This has been a fairly recent development in engineering, having taken place in the last five or six years, and it has conclusively demonstrated itself as a profitable use of engineers' time and effort.

Many people are probably of the opinion that the increase in the amount of automatic control and instrumentation on a unit has cut down the number of men employed in the refinery. This is not necessarily the case. While it has reduced the number of men required to operate a given still, it has also required an increase in the number of men demanded for the maintenance of the instruments. One thing it has done has been to require a higher class or better educated group of men; not only to operate the still but also to maintain the instruments. Modern instrumentation is so complex and multiform that refiners feel a distinct need for instrument courses in the universities. Certainly, there is a definite field for the college-educated man who undertakes instrumentation as a life-work.

The industry, however, does need a number of improved instruments and also new designs. Among these are: faster pyrometers for recording temperatures, the pyrometers to have the same or greater degree of accuracy than at present and they could at the same time be built in a more rugged manner; new designs of liquid-level controllers which would offer us greater flexibility in level control; and better, more efficient and less fragile remote indicating and control instruments for distances up to 500 or 800 feet. (At the present time, remote-control instruments of this type are available but they require an excessive amount of maintenance and they are not as dependable as the standard instruments.) When we get these, shall we be satisfied? Judging from observable trends, we shall voice a demand for still more new designs!

In conclusion, the oil industry is grateful for the coöperation it has received from the instrument companies in the development of new and special control equipment, but we should add that even closer coöperation will be required in the future due to the increasing number and complexity of our control problems.



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WHAT INSTRUMENTS DO FOR

The Power Industry

By E. S. LINCOLN
Consulting Electrical Engineer, New York City

INSTRUMENTS and precision control, either manual or automatic, are required for every step in the generation of electric power and of its distribution to the ultimate consumer. The use of measuring instruments as applied to the power industry begins with combustion under the boiler; the switch that starts the internal-combustion engine and the opening of the gate which puts the water turbine in motion. At the end, voltage must be known and controlled when the generator shafts begin to revolve.

With hydraulic power there is no combustion, therefore fewer measuring and controlling instruments are needed but these are highly specialized, as witness the 500-foot-tall gate-opening controls at Boulder Dam. Direct combustion in the Diesel engine cylinder requires temperature measurements and fuel control, at least—and altogether a greater variety than is found on hydraulic turbines. The third class of prime mover, wherein heat is required for producing steam, requires that instruments and automatic controls be applied to obtain efficient combustion of fuel, to provide sufficient heat units for maintaining correct pressure in the boiler and to provide adequate steam flow to meet the power requirements of the steam turbine.

The greatest advancement of instrumentation in the power industry has taken place in the generation and utilization of steam. In earlier stations only a few instruments such as steam pressure and vacuum gages were used. The modernization of furnaces, boilers and auxiliary equipment through instrumentation is directly responsible for cheap steam power generation. Many modern steam generating stations generate a kwh. for less cost than a hydro-electric station of equal firm power capacity. In 1917 generating stations required 3.03 lbs. of coal to generate a kwh.; today, modern generating stations require only 1.42 lbs. of coal to generate a kwh. In addition to effecting savings (which are passed on to consumers) instrumentation safeguards equipment and protects steam plant operators from life hazards.

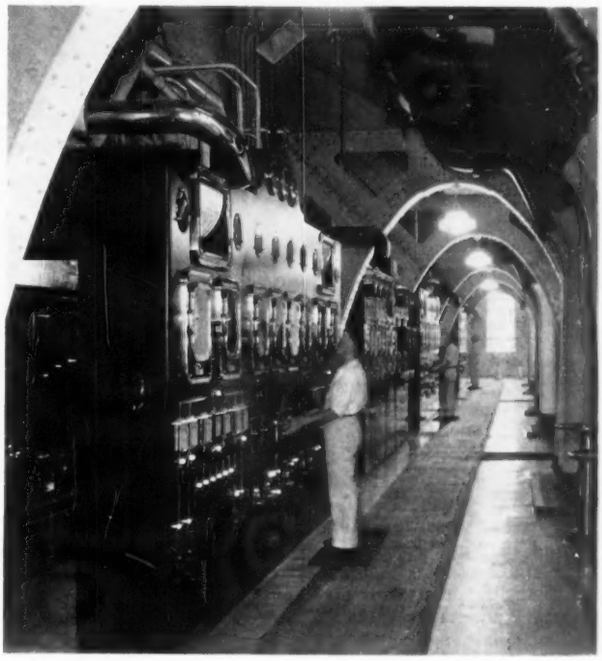
Every step in steam generation requires the use of instruments for efficient operation. Where fuel consumption is great, periodic analysis of fuel and tests of lubricating oils are required. The supplies of fuel and air require automatic control to meet variable steam demands placed upon boilers by changing loads in turbines. Constant steam pressure must be maintained and water evaporated in boilers must be replaced, thus requiring the use of additional instruments and control. Auxiliary equipment such as condensers and feed-water heaters require vacuum, pressure and temperature instrumentation, as well as measurements of leakage, salinity, etc.

In the generation of electric power a constant voltage must be maintained, as well as accurate frequency control on alternating current systems. Generator voltage control, which was a manual job in the early days, has become an important branch of instrumentation; and today there are not only numerous types of generator voltage regulators but also feeder voltage regulators, all assuring the customer a constant voltage regardless of fluctuations in his neighbor's load—or in his own.

Frequency control was not considered an important factor in the early development of a-c. systems and the frequency meter did not appear until a-c. systems had been well established. Today, frequency measurement has attained a higher degree of precision than any other measurement in the generation and distribution of electricity; and frequency regulation a higher degree of accuracy—all due chiefly to the fact that the utility industry has become the people's timekeeper as part of its service in all regions with an a-c. supply.

Through measurements and control the parallel operation of alternators is accomplished and determines the proper distribution of loads among individual generators and generating stations which comprise a complete system. Auxiliary equipment such as exciters and switching mechanisms also require precise control.

In large systems which supply cities with electric service, load supervision is dependent upon the use of many instruments for efficient operation. Supervision of loads, in turn, depends upon systems of telemetering and totalizing the loads in various stations located at long distances from the central control rooms.



Courtesy Ford Motor Co.

Thus far, electrical instrumentation described has comprised that which is necessary for power production and distribution—chiefly the stationary or switchboard types. However, many types of portable instruments are used for testing and investigating purposes of equal importance in the maintenance of power systems. Instruments required for load, voltage, and power factor surveys are examples.

The power industry consumed about one-sixth of the instruments sold in 1935 and it may be safely stated that no other industry, as a whole, is more dependent upon measurements and automatic control. Outside of isolated plants, continuous minute-to-minute control of every item enters into power production, distribution, and utilization.

Instrumentation of the power industry does not supplement labor to the extent that it increases employment directly in enlarged and new stations and extended systems. However, indirectly, additional labor is required not only for instrumentation itself but in industries made possible by cheaper power and the development of electrical science.

WHAT INSTRUMENTS DO FOR

The Rubber Industry

By G. P. BOSOMWORTH

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BORN of the experimental work by Peel, Hancock, Goodyear and Hayward (1791 to 1844) the early rubber industry was interested chiefly in waterproofing fabric and small household articles. In 1861 the first solid rubber cab tires appeared; in 1888 pneumatic bicycle tires; and about 1896 a few enterprising firms began to manufacture rubber tires for automobiles. Little thought was given to instrumentation in those days, the major problem being to design processing equipment. Nevertheless, the rubber industry realized that the automobile industry would grow: it soon began to think in terms of larger production capacity and, with competition in the field, of reducing costs. This produced a demand for skilled chemists and engineers. These men recognized that cost reduction and improvement in quality would require adequate means of measurement and control. Up to that time a pressure gage and hand valve or reducing valve had been considered sufficient in curing processes, and a hand tachometer was something only found in large factories or educational institutions. Timing of an operation was left to the judgment of the operator. Working conditions were arduous.

As the demand for rubber products grew in the period 1910 to 1920, ideas in plant layout expanded and continuous processing became something of a reality. Instruments began to play a major part in facilitating such production methods without sacrifice of uniformity. Chemists and production men were beginning to accept recorders as a necessary adjunct of indicators. Further developments in instrumentation in 1920-1930 produced control equipment having time as one of its functions. With these advantages it was possible for the chemists and tire engineers to write closer specifications with the expectation that they would be met. New compounds and tire constructions were developed requiring greater precision in processing.

During that period the instruments used were modifications of those developed for other industries. Today the instrument industry can offer special equipment suited to the requirements of the rubber industry and can coördinate such pieces of equipment in such a manner that the maximum benefit is derived from each element of the instrument installation.

The rubber industry offers a field for scientific as well as industrial instruments. Instruments today are accepted as necessary to maintain uniformity, to minimize costs and to permit greater production with less physical effort on the part of the operator.

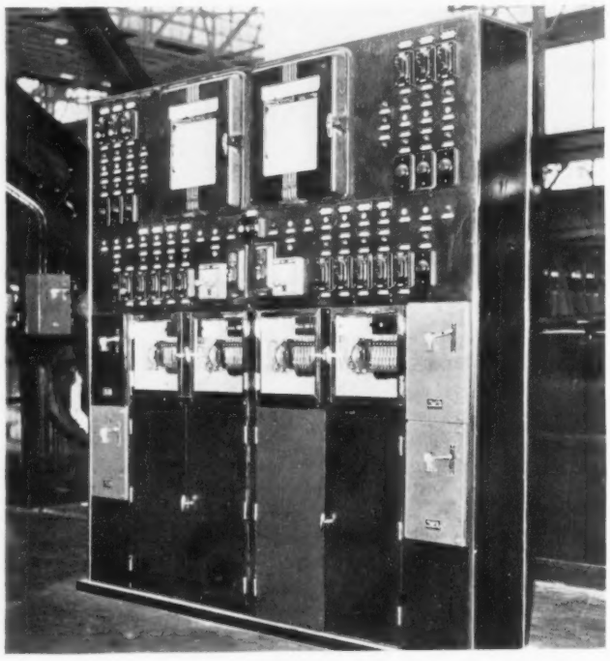


Fig. 1. Designed by the Ford Motor Co., this panel controls the automatic compounding system on Banbury mixers at the Ford Tire Plant.

Rubber industry instrumentation begins in the overseas plantations where crude rubber being prepared for shipment is passed through large drying ovens equipped with temperature and humidity control equipment. Many rubber plantations today can show laboratory and control equipment equivalent to that found in the world's industrial centers.

After it is received in this country the crude rubber has to be "thawed out." It is placed in large heated rooms where temperature and humidity are controlled. At the end of a specified time the material is fed into a masticator in which the temperature and quantity of the water used for cooling or heating the equipment are controlled—generally by hand. This operation, from a temperature control angle, offers a problem typical of many of the processes in a rubber factory. Large masses of material and equipment introduce time lags which are not easily handled with automatic control.

Seldom can the crude material, as received from the plantations, be used alone. Other materials have to be added in the correct quantities and this part of the process generally takes place in a mixing device known as a Banbury. The added miaterials may be solid, plastic, granular, powder or liquid. Fluid meters, weighing equipment and temperature controllers are required. Great progress has recently been made in the automatic compounding of rubber materials. An outstanding example of this is that of the Ford Plant (Fig. 1).

The "usual" compounding room of a rubber plant is rather dusty—and therefore represents waste of materials and unpleasant working conditions. Cycle controllers with automatic weighing equipment using either photoelectric or mercury switches are now making it possible not only to overcome these defects but also to permit more accurate weighing and timing of the process, producing uniformity of the product. The Banbury mixers are cooled with water but only in recent years has the stock temperature been satisfactorily measured and recorded. At first vapor-pressure systems were used, but heat conduction from the bulb to the side frame caused errors as high as 80°F. It was then that the pyrometer won acceptance. This particular development was sponsored by the rubber manufacturers. It is believed that the Firestone Company was the first to use pyrometric instruments successfully on Banbury mixers. Most rubber manufacturers are now using recording pyrometers.

The material after being processed in the Banbury is fed to a mill. At this point sulphur is generally added and

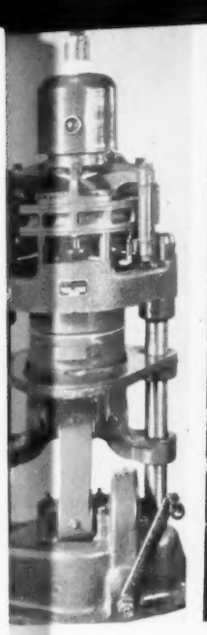


Fig. 2. Extrusion Plastometer. (Dillon—Firestone T. & R. Co.)

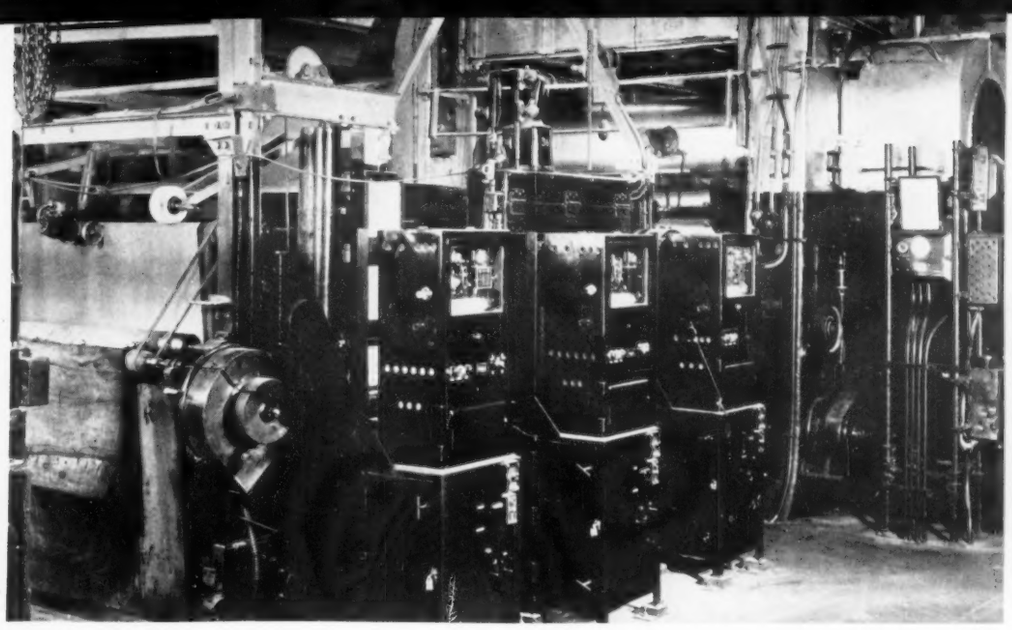


Fig. 3. Thickness recording gage for calendered fabrics. (Roy W. Brown —Firestone T. & R. Co.—Leeds & Northrup recording instruments.)

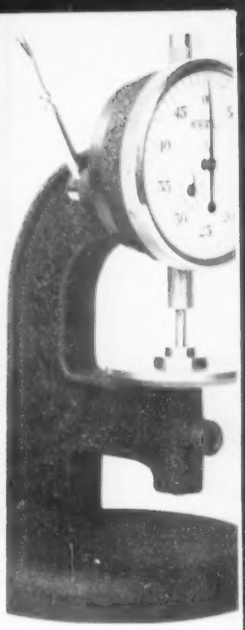


Fig. 4. Dial micrometer. (Federal Products Co.)

further plasticating and mixing are done. Cooling water is required in the rolls to remove the heat produced by the mechanical work done on the rubber. Since cooling water is one of the major items of expense in the rubber plant, anything which can be done to insure its correct minimum use would result in a worth-while saving. Surface temperatures are important and various thermoelectric or resistance type instruments have been used.

In the Mill Room it is necessary to control the specific gravity and plasticity of the stock. For this purpose most rubber manufacturers have a control laboratory located at some convenient point to which samples are rushed by pneumatic tube systems. Here the specific gravity of the samples may be measured by methods going back to Archimedes, but the plasticity is determined by such new instruments as the one designed by Williams, Marzetti and Dillon (Fig. 2). At the same time sample cures are made of the stock as a check on its suitability for future processing. The laboratory platen presses and autoclaves, of course, are equipped with temperature recorders, controllers and automatic timing devices.

Cotton plays a major part in the manufacture of tires. It is received in 250-500-yard rolls which are stocked in warehouses maintained at uniform humidity and temperature. Pre-processing of the fabric consists in dipping it in a solution of rubber. The fabric is then dried in temperature-controlled ovens and the dipped fabric is next passed through a calender where gum is applied. The calender rolls are heated or cooled to the correct temperature to facilitate application of the gum to the fabric. A similar time-lag problem arises on the calender as on the Banbury and other heavy machinery. At present resistance thermometers and thermocouples are used, but without much success. Here is an opportunity for instrument engineers to solve a perplexing control problem which is as old as the industry.

In the manufacture of tires it is necessary to maintain uniform thickness and weight per square yard of the treated fabric. A calender in the course of a day can produce a considerable amount of skim coated fabric representing a large material cost. Rigid specifications are set up for the finished product. The process cannot easily be stopped to permit weighing the material or measuring its thickness. To facilitate such measurements various instruments have been developed. There are available continuous thickness recorders which measure not only the overall thickness of the finished material but also the thickness of the gum applied to each side of the fabric. These instruments are of the magnetic type. Representative types are those developed by Roy Brown and Schuster (Fig. 3). For continuous measurement of weight there are available direct-weighing scales of the rubber conveyor type. For continuously measuring the total mass of the material being processed there is available an instrument manufactured by Foxboro which depends for its action upon the dielectric characteristics of the material passing between the plates of a capacitor. Dial micrometers (Fig. 4) used as a laboratory checking source of thickness measurements have standard foot pressures and diameters. This is necessary on such a compressible material as rubber.

The tubing machine has supplanted to a large degree the calender for processing the rubber compound into desired cross-sections for tubes and treads. In common with other similar machines, this equipment does considerable mechanical work on the material, producing heat, which if too high becomes injurious to the product. Temperature control therefore is a desirable feature. It also is necessary to maintain uniform weight per unit length of the extruded material and to cut it into correct lengths for future processing. The weight control equipment has been largely built around the lever type scale. Tachometers are quite a help to the production supervisor and operators.

The processing previous to the assembly of the individual elements of a tire must be carried out with sufficient degree of accuracy to meet the specifications for the assembled product. It is useless to have a high degree of factory control on one part of the production line and not on another. The product as it gradually approaches the finished state becomes more valuable; the loss would be greater if a complete article had to be discarded by the final-inspection staff.

Curing methods have probably undergone the most extensive changes of any used in tire manufacture. In the beginning, a tire was made in two portions: the fabric base and the tread. Each of these parts was semi-cured and then assembled on an iron form and the whole finally cured. This probably was the age of the greatest amount of hard manual labor that the tire industry has seen. At that time the troubles in manufacture overshadowed the control problem. As production increased, the limitations of heavy equipment became increasingly evident. In addition to this the chemist and development engineer had made available new compounds and tire constructions which permitted changes in the methods of processing. However, such changes required that more rigorous specifications be met. The advent of the vertical pot heater occurred at the time when generally the only forms of control were a weighted-lever type reducing valve or manually-operated steam valve with an indicating pressure gage. The checking of the curing conditions through the use of resistance thermometers and thermocouples made it possible to show that uniformity in curing conditions could not be obtained by even the most skillful use of pressure gages and reducing valves. Leakage of air into the steam in the heater dis-

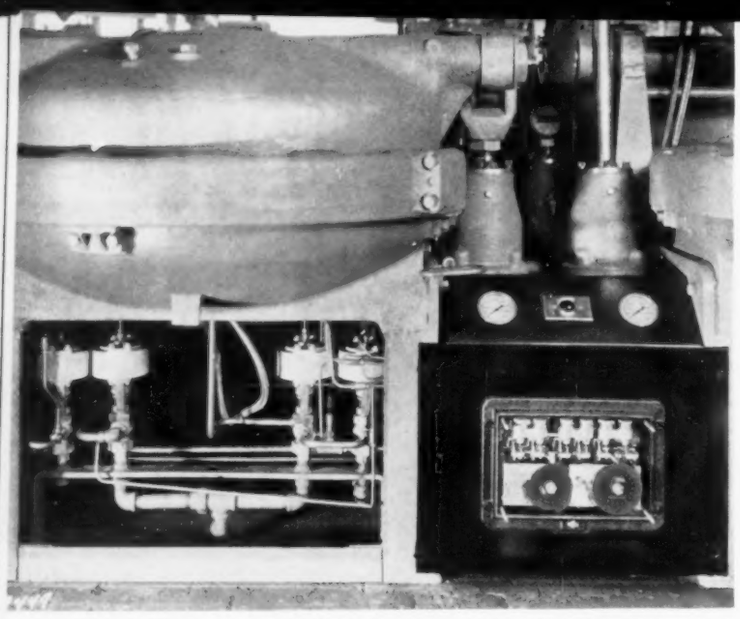


Fig. 5. Automatic individual vulcanizers. Summit Molds, Bristol Cycle Control—Sponsored by Firestone T. & R. Co.

turbed the vapor temperature relationship. A natural step after this was the adoption of a recording thermometer—which evolved into temperature controllers for the control of the curing process.

The valve equipment on pot heaters was relatively large and it was found that quality could be improved and the work of the operator reduced by using remote-controlled valves with electric, hydraulic or pneumatic operation. In the first years of instrumentation in the rubber industry it was sufficient to indicate, record and control certain individual conditions of the process such as temperature and pressure. The logical steps after measuring conditions are to record them and eventually to control them automatically, with time as one of the automatically-controlled processing conditions. We now find a temperature controller generally working with or incorporated in a cycle control.

The tire curing process has in recent years undergone a further change. The curing time has been reduced and the hard manual work has been largely eliminated since the operator is no longer required to handle the molds. The pot heater for curing a number of tires at once is being replaced by a smaller curing unit known as the watch-case or jacket mold. These curing units are arranged in groups so that one operator often handles as many as fifty molds. In this system the operator progresses along his group of units, only handling at one time a single tire. It is in this type of curing that instruments have done an outstanding job in permitting the operator to maintain schedule without having to go through a complicated, hard-to-remember, fatiguing routine for each curing unit. This has been made possible through the use of cycle controllers which furnish the various steam, water or air supplies to the process—each at the correct time. The use of such automatic equipment (Fig. 5) permits the chemist to specify more complex curing conditions, producing a better tire, with the knowledge that they will be accurately maintained. Since the jacket molds are each essentially a miniature pot heater, there has been an unprecedented demand for cycle controllers and small diaphragm or solenoid valves. The complexity of the cures necessitates also that the control equipment be flexible and quickly adjustable to different specified curing conditions.

It is a matter of common knowledge that today's tires are better than those of twenty years ago. This is largely due to improvements in tire design and compounding, requiring higher standards in processing. Instruments have been responsible for the ease with which these new standards have been attained.

There has been considerable progress in tube curing from the old straight-pole-wrapped type in which the flat calendered material was wrapped around the tube and then placed in a steam-heated vulcanizer for curing. Here again we find that the modern way is to use individual vulcanizers somewhat similar to those used for tires. They are equipped with cycle controllers to initiate the various valve operations which govern the flow of steam and air required for the cure. The duration of this operation is short (7 to 20 minutes) and the operator could not possibly go through the required motions on a large number of vulcanizers with any degree of accuracy without automatic equipment.

Mechanical goods have grown to be of as much importance as tires and tubes in the rubber industry. A number of primary processes found in the tire industry are also used in the preparation of mechanical goods, such as the preparation of the crude rubber, milling, Banbury mixing and tubing. From this point on the process differs slightly in that platen and extrusion presses are used for curing. The presses are generally heated with steam, hot water or electrical resistance units. High-pressure water or oil is required for the closing mechanism, involving the use of quite expensive valve equipment. Cycle controllers are being increasingly used to facilitate production with uniformity of product. Temperature control of the material processed in a platen press is not as successful as in a jacket mold or pot heater. This is not due to the instruments but rather to the construction of the presses. Presses are relatively inefficient heat transfer units. To improve these conditions, changes are being made in the design of presses which will permit the accuracy obtainable with today's temperature control systems to be fully realized. It is no longer considered the best of curing control methods to use steam pressure as a basis of temperature measurement. Cures today are specified, as in tires, by temperature and it is believed that the method of control should be the same.

In the Mechanical Goods section of the industry, correct control of weight of the individual pieces of uncured stock is a necessity. Considerable money can be saved through accurate weighing to eliminate waste. Time recorders on this type of equipment help the production supervisor to obtain maximum production from such curing units.

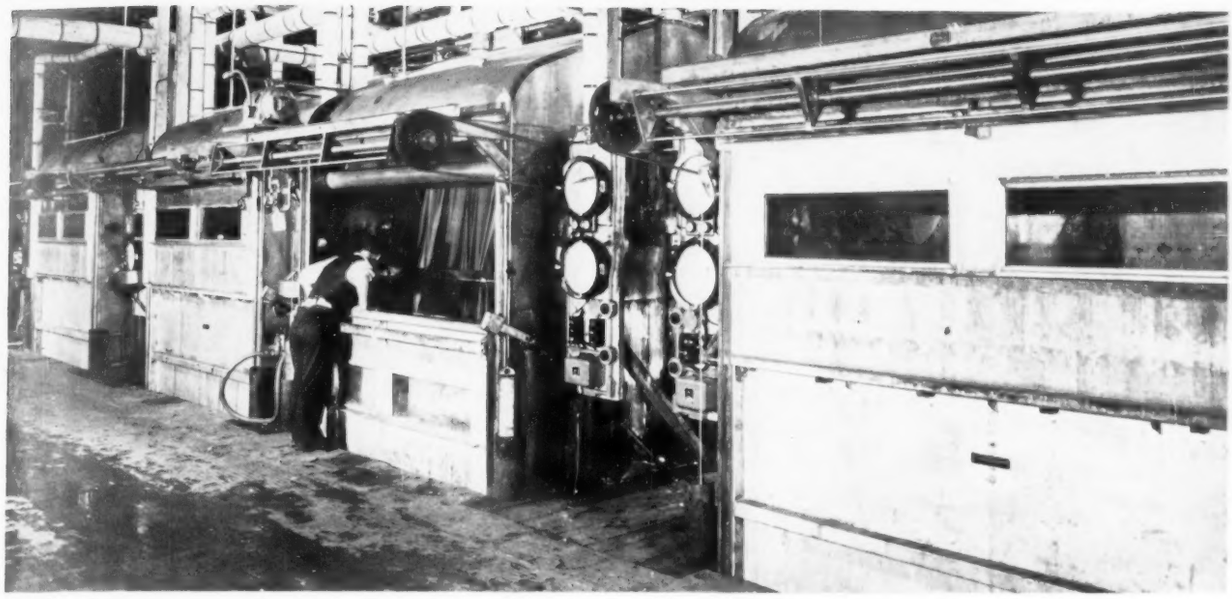
In the rubber industry the production of steam, hydraulic power and compressed air for processing requires considerable instrumentation in the power house. These services must be accurately metered to establish costs and check waste. Records of pressures and/or temperatures of these services are of value in case of production troubles. It is wrong, although common, to blame a control system for breakdown of a process if the correct services are not available at the header valves.

A factory processing rubber uses a considerable number of instruments and control valves. The maintenance of such equipment should be in the hands of an instrument division whose personnel is trained in the correct installation and operation of the instruments and valves involved. Such a department should be one which has the confidence of both the production and technical staff of the factory.*

The scientific instrument industry has furnished many special instruments for checking the product at various stages of its manufacture. It is necessary during the process to check plasticity, hardness, density, thickness, weight, aging characteristics, tensile strength and abrasion resistance. There has been a gradual shift of the scientific instrument to production use. Today one can see production operators using such instruments as dial micrometers, viscosity devices, plastometers, penetrometers and standard tensile testing machines with an understanding of the property being measured.

It is hard to visualize today's production methods without the benefit of instruments. The steady flow of materials from the receiving platform to the warehouse and a satisfied customer is only possible if uniformity is maintained at every stage. It is believed that a considerable part of the satisfactory service life of the various rubber products is due to instruments. They now have the confidence of the production departments and the sponsorship of the technical division.

*References on instrument-department organization: (1) Roy W. Brown in Chapter IV, Part One, Behar's Manual of Instrumentation; also *Instruments*, Feb. 1932, pages 27-32. (2) G. P. Bosomworth, *Instruments*, Nov. 1935, pages 285-289. (3) A. G. Mood, *Instruments*, Dec. 1936, pages 331-334, and Jan. 1937, pages 15-18.



"The modern totally-enclosed, insulated, stainless-steel piece-dye kettle is equipped with temperature-time cycle controllers."

WHAT INSTRUMENTS DO FOR

The Textile Industry

By H. F. PERKINS
Engineer in Charge of Mechanical Research, Pacific Mills, Lawrence, Mass.

WITHOUT measurement and control instruments, there would be no modern textile industry. "Survival of the fittest" is as true in industry as it is in biology. Industries which have shown the most progress and the establishments within the various industries which have survived and still are successful are those which have insisted upon keeping "fit." This has meant a willingness to spend money for modern machinery, for new equipment, and for research. In fact, the extent of this latter activity has become a barometer of industral progress.

Research, at once, suggests instruments, without which such a department would not get far. Laboratory instruments may or may not be representative of those found in common use throughout the plant. It is a fact, however, that yesterday's tool of the technician is today's guiding star for the machine operator. It aids him in more easily and intelligently performing his task.

The modern generation is instrument-minded. There is no mental problem in connection with the introduction of instrument control. More young men, throughout our plants, have had some technical instruction than ever before. I refer particularly to the boys who have taken advantage of our trade and evening schools, and especially the evening courses offered at the Textile Schools. These boys are quick to make use of the benefits found in automatic devices. This was not so true of the older generation.

It is no secret that the textile industry has been accused of being one of the least progressive of our major industries. This accusation is probably due to ignorance of what really has been accomplished over the years, and the fact that there has been nothing spectacular about it. Progress has been made steadily but surely, and in the last decade has at least approached the spectacular.

To cover completely the whole textile industry is, naturally, too large an order for this one article. The woolen and worsted division is fairly representative, however, and probably presents more problems than the other branches of the industry. This division, therefore, will be followed in some detail to show the extent to which instrumentation now obtains.

In the so-called manufacturing departments of a worsted mill we have many examples of modern instrumentation. The automatic control of humidity alone would justify the opening sentence of this article. The processes of carding, combing, gilling, drawing, spinning, twisting, winding or warping—all of which are involved in the production of yarn—together with the weaving of yarn into cloth—all these would cease to function properly if humidity were not uniformly controlled day in and day out throughout the year.

Several types of humidifying systems have proved entirely successful over a period of many years. Their respective merits will not be discussed. Suffice it to say that their control is entirely automatic and reliable. It should be added, however, that the automatic control of the heating in the Northern mills, while not imperative, is desirable in connection with humidity control. Uniform conditions are more easily maintained and savings in the steam plant are effected by automatic control of room temperatures.

Strange as it may seem, the greater savings are to be made over week-ends and holidays, when the plant is shut down, and in store houses or buildings not having operating machinery. Under these conditions, thermostatic control will maintain safe temperatures against freezing, or damage to product, without wasting unnecessary heat. In rooms filled with running machines, the entire horsepower required to drive these machines is eventually dissipated as heat. This means that in many rooms no additional heat is required during working hours. It also demonstrates how much better is our automatic thermostat for controlling such a situation as compared with manual control.

Instruments for the control of temperature or pressure, or both, are considered necessary at several points during manufacture. The question sometimes comes up as to whether an indicating or a recording type of instrument should be used. While there is no set rule (and often personal preference is the deciding factor) in general, indicat-

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ing instruments are satisfactory for continuous operations while recording instruments are practically demanded for batch operations. Indicating temperature controllers are used on wool scouring trains and backwasher bowls, although recorder-controllers are often used on the dryers. The essential is to have controllers, as it is well known that excess temperature is harmful to the wool.

The steaming of yarn is a batch process and the record is important. Whether it be a vacuum or pressure steamer, each lot is recorded for the time it has been steamed and the exact conditions obtaining. There are also continuous steamers but these are governed by the speed of the apron and are not subject to much variation.

Automatic control has found one of its most fertile fields in the slashing department, where the several operations required in this process are successfully handled automatically. The size cooking kettles are controlled by time-temperature recorder-controllers. The desired cooking cycle is set up on the instrument. This includes the time allotted to bring the batch to the boil, length of the boil, shutting off the steam at the end of the cooking and at the same time stopping the agitators. Every batch is identical, and its record is on the chart.

Here, certainly, is vast improvement over the former hand method, particularly with multiple-shift operation, when it becomes a question as to who forgot to watch the clock or stop the agitators, and thereby ruined the batch. It also is gratifying that the same operatives as before are now handling these automatically-controlled kettles with so much better results, and with no trouble in manipulating the instruments.

The practice of stopping the agitation at the end of the cook is not followed in the cotton, where a much thinner size is used. Here, the size is circulated through a loop system feeding the vats as required. The size vats are regularly equipped with automatic temperature and level recorder-controllers. These two functions may be performed by a two-pen instrument operating from two bulbs through separate tube-systems; the temperature bulb being vertical and approaching the bottom while the level control bulb is horizontal and at the top of the vat, since it is the exposed position of this bulb, when the level drops, that causes more size to be admitted. In shallow vats, where the size passes through rapidly and temperature change is slight, good operation is effected by dial thermometers placed within easy visual distance of the operator and connected to the vats by the usual flexible tubing.

Temperature recorder-controllers are proper equipment for the drying chamber. Information is certainly needed at this point if warps are improperly dried. Excess temperature is also to be avoided. It not only is a waste of steam but it also serves no good purpose to overbake the size.

Another advance in automatic control is being introduced on the various types of slashers. This is the so-called speed control, whereby the speed of the machine is governed by the desired moisture content of the warp as it approaches the beaming-off end. The particular method used to accomplish this result varies with different makers. A change in moisture content is accompanied by physical or electrical changes which may be harnessed to operate the speed changing device. Typical examples now in operation include controls actuated by changes in static electricity, in resistance to an electric current and in the humidity of a sample of air drawn through the surface of the warp. So far, most progress has been made on the cotton slashers but development is proceeding rapidly on rayon and on wool.

Passing on to the dyeing and finishing side of the textile industry and still following the woolen and worsted processes, we find many further applications of automatic control. The wet finishing, comprising as it does many scouring steaming operations, is well supplied with both indicating and recording temperature controllers. Here is opportunity for making real savings, because of the enormous quantities of hot water used.

Most of the control instruments used in the textile industry are for improving quality and particularly for pro-

curing uniformity in the many processes. They are doubly valuable when waste of heat may be prevented at the same time. Continuous washers of whatever type, furnish a good example of this feature. Temperatures should be controlled at as low a point as is consistent with good scouring. This becomes more important in rinsing sections where the water overflows to waste. In boiling sections, excess steam simply goes up the ventilator. I have in mind the installation of a steam flowmeter on such a machine, to determine how serious this loss might be. This machine was a large user of steam and the meter gave us a record of its amount. The next step was to cut down at various points, checking required temperatures, and carefully following the scour. The steam consumption was finally cut nearly in half, with no sacrifice of quality or output. The flowmeter pointer was then used as the operator's indicator for future valve settings. Hand control has since been supplemented by instrument control to maintain more easily and surely the correct conditions.

The dyeing operations which are next in order, present many interesting applications for automatic instruments. Chief among these is the modern, totally-enclosed, insulated, stainless steel piece dye kettle. Time-temperature recorder-controllers have long been standard equipment on kettles. The familiar open type wooden kettle, even with automatic control, is watched for a "hard or soft" boil and other characteristics followed by the dyer. In the new type kettles, although equipped with windows, these observations are not so easy. Also, being tightly sealed, surprisingly little steam is required to maintain a boil, all of which means that these machines cannot be operated intelligently without automatic control.

The time and temperature cycle to which these instruments are set varies greatly, of course, because of the many styles of cloths to be dyed. Here, again, the new stainless steel kettles have put an extra burden on the instruments due to their so-called universal service. In other words, a pink shade may be followed by a black, then back to a green, with the fabric changing at the same time, and all this in the same kettle.

The controlling cams must therefore be readily adjusted or exchanged to suit these varied requirements. This is quite different from an application where, once set, the instrument functions day in and day out with no further attention. All of which leads me to say that the service required here is the severest and the most exacting to be found in the mill.

As to the cycle itself, it may be anything that the dyer wishes, and dyers do not agree on what is best practice. The instrument makers, therefore, have built their apparatus so flexible that almost any requirement may be met. Additional gadgets may be had, often at small cost, for operating a signal, opening or closing the steam valve at a particular point, or performing some other desirable work.

The carbonizer is well supplied with automatic controls. Temperature recorders control the several drying chambers from the wet end through the baker. The acid tank with its pH controller is a joy to the operator. When the question is now asked, "Has anything happened to the acid strength?" he can reply with the well known phrase of New York's former Governor, "Let's look at the record." These instruments have proved extremely satisfactory.

Subsequent finishing operations comprise many types of dryers, most of them equipped with temperature controllers. The tenter dryers require, in addition, automatic guiders for feeding the cloth into the pin type chains used on wool cloths. An added refinement in control on these machines is a device for correcting diagonal warp threads where a piece has become "skewed" in some previous operation. The latest development along this line is automatic and is actuated by photoelectric cells.

Speed controls, such as described for slashers, have been developed also for these cloth dryers. Efficiency is their object in that the dryer should run at the maximum speed allowable without exceeding the desired moisture content in the cloth leaving the dryer. And here again, more progress has been made on the cotton side than on the worsted.

Steaming and decating machines which are responsible for some of the beautiful soft finishes of worsted and wool cloths, should be equipped with recorders to show the time, temperature, pressure or vacuum for each load, as was described for the yarn steamers.

In summing up the foregoing applications of instrument control, it is evident that only the high spots have been covered, and that the instruments used at these more important points have been of the best type, comprising record charts or indicating scales, or both, with compressed air or electrically operated valves and remote bulbs connected by flexible tubing. There are, however, many processes, especially in the wet finishing, and yarn or stock dyeing departments, where the simple self-operating temperature regulators, together with dial or straight-scale thermometers, are of great value. The same applies to pressure regulators accompanied by suitable gages.

The general subject of instrumentation would not be complete without reference to at least a few of the newer instruments now in more or less common use. They are not in the category of automatic controls, but they do occupy an important place in the better manufacturing of today.

One example is the stroboscope, with which we can quickly check the perfect pick of a loom, bad spindles, if any, along the rail of a spinning frame, or an imperfectly running shear. Another is the load indicator whereby any difference in the pressure at the two ends of a mangle roll are shown by the relative position of two pointers, one for each end. This device, developed for the paper industry, has found favor in textile finishing operations where an even squeeze must be maintained. It is applicable to hydraulic and pneumatic loading, but particularly valuable on the more common weight and lever type mangles which are in no way self-balancing.

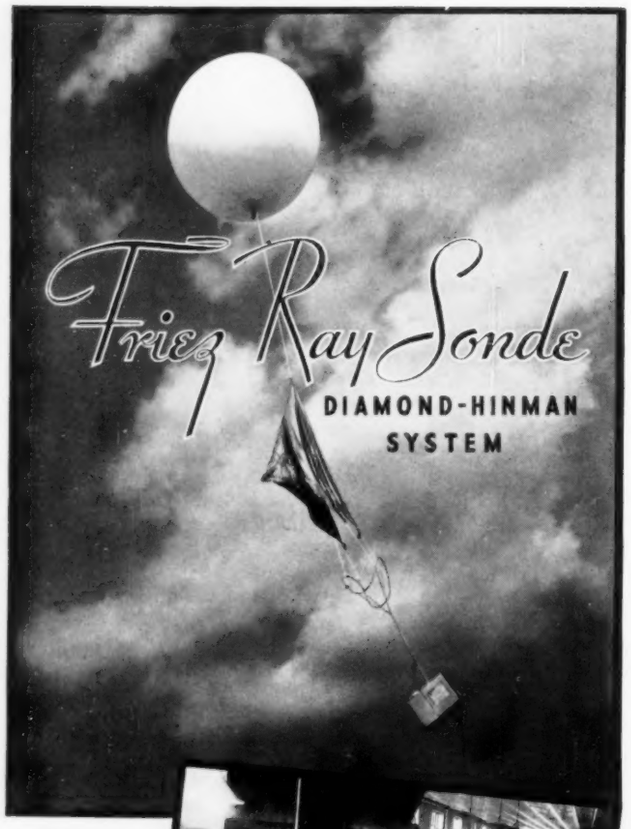
Tachometers with or without totalizing yardage counters are becoming standard equipment on many machines. Stop motions of every conceivable description protect the product from injury at most of the stages of manufacture. Automatic scales save time and mistakes at many checking points along the way. The clever use of a large dial scale combined with a dumping hopper and a conveyor apron comprise the principal parts of a new wool blending device. A recent publication of the U. S. Government calls this the most important improvement made in the last ten years in connection with this part of woolen preparation.

The manufacturing processes required for cotton, as far as automatic control is concerned, are not greatly unlike those already outlined. The methods of producing rayon yarn and silk yarn are different, but space does not permit their discussion. It is in the finishing plants for these fabrics that are found many of our best examples of automatic control.

This is not due to more complicated machinery or processes, but because of the huge volume and the speed with which it is handled. In place of a few hundred yards of one style followed by a similar amount of another as is the usual case in wool and worsted, cotton runs by the mile. Therefore, opportunity is had in these long continuous runs to establish successful speed controls which have been mentioned in connection with slashers and dryers. These controls, as previously stated, are governed by a predetermined moisture content in the dried goods.

Combination of certain processes in so-called ranges have brought out automatic synchronizing devices for maintaining correct tension of the cloth between the different units. For temperature or pressure regulation in the various vats, kiers, etc., the apparatus as already described is, of course, equally applicable.

In conclusion, it should be stated that the principal object of this article has been to review how dependent upon automatic control the textile industry has become. No attempt has been made to discuss savings *versus* investment, or to describe details of installation. The fact that the various processes are equipped as described speaks for itself, and should be proof enough that without measurement and control instruments, there would be no modern textile industry.



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Life Cycle of A RaySonde

from Assembly to Stratosphere and Back Again

1. Factory production view showing manufacture, calibration and assembly of parts.
2. Shows RaySonde undergoing final inspection before shipment.
3. Inflation of balloon to predetermined weight sufficient to carry RaySonde aloft.
4. RaySonde attached to parachute by shock absorbing spreader just before release.
5. RaySonde just after release—headed toward the stratosphere at approximately 200 meters per minute.
6. The first RaySonde recovery returned from the flight program launched by the U. S. Weather Bureau during July 1938.

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WHAT INSTRUMENTS DO FOR

The Transportation Industries

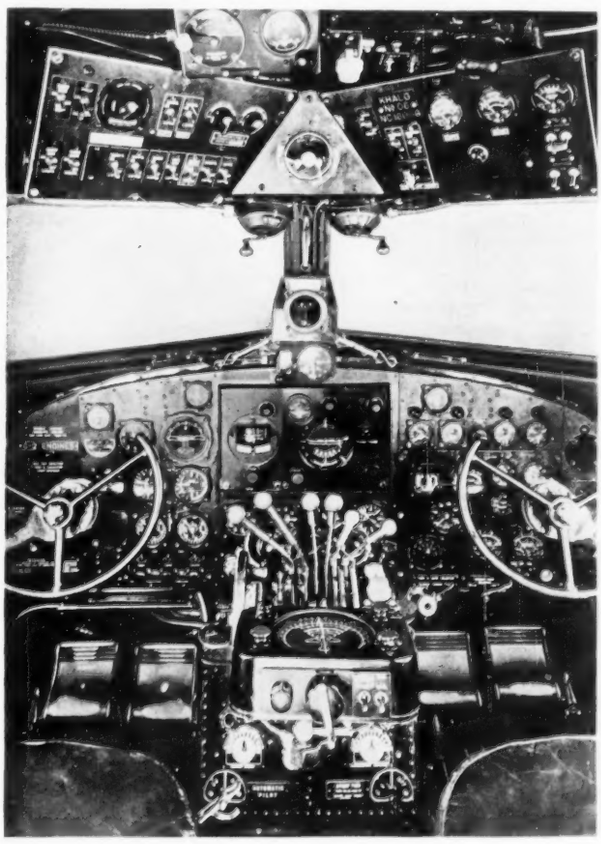
I-Aircraft

By W. G. BROMBACHER
Chief, Aeronautic Instruments Section, National Bureau of Standards, Washington, D. C.

NORMAL operation of airplanes is becoming more and more dependent upon instruments and controllers as the size of airplanes increases and as the ideal of 100 percent safe and efficient operation even in adverse weather is being gradually approached. The number of instruments has increased to such an extent that in large airplanes it is beyond the capacity of one man to watch them all. The use of automatic controllers and the integration of instruments tend to reduce the fatigue of pilot and crew.

Major instrument and controller developments now in progress are those designed to facilitate: (*a*) landing of aircraft during conditions of poor visibility, (*b*) determination of position and altitude when flying with the ground invisible in order to prevent crashing into mountain sides and colliding with other aircraft and (*c*) air conditioning in high-altitude flying. In landing during poor visibility reliance is now placed primarily on radio devices.

Many other instrument problems exist, and are continually arising, which require improvements and modification of existing instruments. These improvements and modifications, while not spectacular in nature, must be made in the interest of increased safety and efficiency of operation. At present there is a trend toward the use of various electric distant-indicating instruments. Experiments on various ways of illuminating the instrument board are being made. Aircraft instruments must be light in weight and must operate reliably and accurately when subjected to variations in pressure and temperature, and to vibration, although the use of shock-mounted instrument boards is becoming general.



View in pilots' compartment of American Airlines' Douglas DST Sleeper showing some—not all—of the instruments. The new Sperry Direction Finder may be seen in the lower center, just below the engine control knobs

Instruments on airplanes may be classified as those used for (*a*) navigation, (*b*) automatic piloting, (*c*) instrument landing, (*d*) automatic instrument landing, (*e*) powerplant control and (*f*) ice warning. In addition a number of special instruments are needed in (*g*) flight-testing airplanes, (*h*) aerial photography and (*j*) airships and balloons. In view of their limited use, (*g*) to (*j*) will not be discussed.

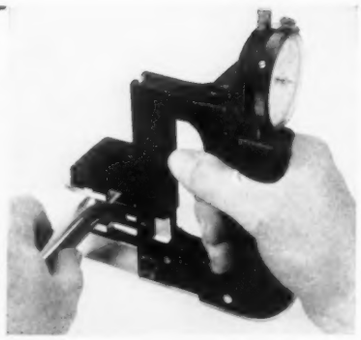
Navigation Instruments

Navigation instruments are here defined as those which indicate the attitude, altitude, speed, direction of travel, and position of the airplane on the earth's surface. At present the attitude (fore-and-aft and lateral tilt) of the airplane is indicated by the Sperry gyroscopic horizon[1] which was first used by Major J. H. Doolittle in 1929 in the Guggenheim Fog Flying Experiments. This instrument is a long-period pendulous, air-driven gyroscope with three degrees of rotational freedom, the rotor axis of which is normally vertical. Should the rotor be deflected from the vertical as may occur in normal maneuvers, it returns to the vertical in the most direct path, due to the action of a torque produced by a jet of air controlled by pendulous valves.

The magnetic compass[2] is the principal means for indicating the heading of the airplane. A steady improvement in the performance of the magnetic compass as a result of many changes in design has taken place in the last ten years. In order to determine the track over the ground when flying by the magnetic compass the drift of the airplane due to side winds must be known but cannot as yet be measured when the ground is not visible. Therefore on main airways and in travel toward a radio station, radio beams and radio compasses are used during poor visibility. Radio beams, if undistorted by atmospheric conditions or by topography, give a straight course, independent of side winds, to the radio transmitter; in the presence of side winds the radio compass guides the airplane to the radio station along a parabolic track. Radio beam indicators and radio compasses have been under constant study which has resulted in much improvement in their reliability. The latest step forward is the Sperry-RCA automatic radio direction finder which indicates the magnetic bearing of the radio station and the relative bearing of the radio station and the heading of the airplane.

The magnetic compass is unreliable during turns. The gyroscopic turn indicator was developed in 1918 to indicate the flight conditions under which the compass is reliable. In the Pioneer instrument the precessional torque of the rotor, the axis of which is normally horizontal, is balanced by a spring, the deflection of which is proportional to the rate of turn. Recently Kollsman has developed an ingenious turn indicator in which the properties of a liquid jet impinging upon vanes are utilized to indicate a turn.

To obtain the heading of the airplane during turns, the Sperry directional gyro[1] was developed and first used in 1929 with the gyroscopic horizon. It is an outstanding example of



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the extreme care which is necessary in the manufacture of many aircraft instruments. The instrument is essentially a free gyroscope with the rotor axis normally horizontal. The orientation of the rotor axis can be set manually to obtain a reading of the card to agree with that of the magnetic compass. This setting must be made at intervals of about twenty minutes in order to correct for extraneous precession of the rotor. A vacuum pump furnishes the airstream required to operate the rotors of the gyroscopic instruments.

In order to eliminate the necessity of resetting the directional gyro, the instrument is now being modified by Sperry so as to maintain the rotor axis in the North-South plane by means of a stabilized magnetic compass. Several experimental models of the modified instrument, known as a gyro-magnetic compass[1], have been constructed.

The earth inductor compass may again find application as it did in the late 1920's particularly in view of the need of repeaters in big airplanes where the pilot and navigator are separated and, perhaps, as the direction element in an automatic pilot, when a stabilized instrument is available. Among relatively recent developments, none stabilized, are the West compass, depending upon an electric capacity placed within the bowl of the magnetic compass; the Holmes electrolytic compass; and the Purvis compass in which the indication depends upon a coil with a core of Permalloy, fed with an alternating current. It is understood that other developments are in progress.

Drift can be measured only when an object on the ground or on the water is visible as a reference. The angle between the path of the airplane and the compass heading is determined by observing the object through a peep sight equipped with sighting wires. The more complex instruments contain an optical system. Development of drift sights is being particularly emphasized by the air services of the Army and Navy. Its importance lies in the fact that simple drift measurements serve to correct the heading to secure the desired track. Further, the velocity of the airplane over the ground[2] is determined by measurement of the drift on two courses at a given air speed. Alternatively, the ground velocity may be obtained from a single drift measurement, by timing at a known altitude the passage of an object on the ground between two cross-wires on the drift sight.

When the ground is not visible and radio methods cannot be used, the "line of position" of the airplane is determined from observation of the altitude of celestial bodies. These observations are made with the aircraft octant or sextant. The Pioneer octant and the Bausch and Lomb sextant[4] have been available for many years. Minor development persists in an effort to increase the ease with which they can be used in making observations at night or day. Adjustable bubble levels which are used as the horizon in these instruments required intensive development to secure reliable operation.

Air speed, the speed of the airplane relative to the air, is measured by the differential pressure developed by a Pitot-static tube[3]. A difficult and as yet unsolved problem is the selection of a convenient mounting position for the tube so as to secure at all air speeds true differential pressure and true static pressure, the latter needed for altimeters and rate-of-climb indicators. Pitot-static tubes are electrically heated in order to prevent closure of the openings by icing. The air-speed indicator[3] is a differential pressure gage calibrated in miles per hour or knots. Extending the speed range of the indicators and tightening the performance requirements has necessitated re-design of the indicators in the past few years. Diaphragm capsules of beryllium copper are now generally used in high-range, sensitive indicators.

Altimeters[5] of the barometric type are used to fly at a constant pressure level, to clear obstacles and to determine the altitude, particularly in landing. Altimeters, which are essentially pressure-measuring instruments, are calibrated in accordance with the altitude-pressure relation of the U. S. standard atmosphere[6]. Within the last ten years the outstanding accomplishment has been the production first by Kollsman, followed by Pioneer, of the sensitive altimeter. In its commonest form the main pointer deflects one complete revolution per thousand feet change in altitude. The range of indication is 35,000 feet. When required, instruments can

be obtained which are temperature compensated over the whole range of indication. In the latest designs the elimination of minor errors has been stressed. Emphasis at present is on improving the convenience and accuracy of the barometric pressure setting methods used in resetting the altimeter pointers in flight when the pilot is informed by radio of changes in the air pressure at the ground level.

Absolute altimeters, indicating the height of the airplane above ground, are at present in the experimental stage. Two types, the sonic and the radio, are most promising. In both a signal is sent from the airplane, reflected at the ground level, and received again at the airplane. Essentially the time between emission and reflection is taken as a measure of the altitude. The successful development of a radio altimeter has been recently announced jointly by the Western Electric Co. and the United Air Lines.

Greater sensitivity in indicating departures from level flight is obtained from the rate-of-climb indicator. The instrument is also used to indicate the rate of change of altitude in steady climb or descent. The indication depends upon measurement of the small differential pressure obtained at the two ends of a capillary leak connected to a volume. Recent improvements by Pioneer and Kollsman are (*a*) compensation for changes and for rate of change of instrument temperature and (*b*) compensation for change in calibration with altitude (pressure) inherent in using the altitude-pressure relation of the standard atmosphere.

Automatic Flight Control

The Sperry gyropilot[7], generally used in this country, dates back in its present form to 1933. It automatically operates the controls of the airplane to maintain straight, level flight and can be used in making turns. The controllers are the directional gyro for flight direction, and the gyroscopic horizon, together with an altimeter for maintaining a level flight path. Turns are made automatically by setting the directional gyro to a new course.

Instrument Landing

Quiet, persistent development of methods and instruments for making landings in poor visibility has been in progress during the last ten years, with the pace greatly accelerated in the past two years. The National Bureau of Standards developed a curved radio beam in the vertical plane to guide the airplane down to the landing[8]. Directional guidance in the horizontal plane is furnished by another radio beam. Development of this method of guidance has been carried on since 1933 by several organizations. The next milestone will be the installation in the near future of this landing system with modern improvements at Indianapolis by the Civil Aeronautics Authority.

Many variations of the above system and other methods of instrument landing have been proposed or are under development. Of these only the system developed by the Army Air Corps[9] will be mentioned. This differs from the above method in that a straight line glide is made into the landing field without requiring vertical guidance from a radio beam. The ground equipment is portable and furnishes guidance in the horizontal plane and an indication of position relative to the airport.

The main reliance in the more promising methods is upon radio. In general tranmitters furnish beams for guidance in the vertical and horizontal plane and marker beacons serve to determine position relative to the airport. On the airplane special radio receivers with the necessary indicators are used. In all systems the altimeter and in some measure, the rate-of-climb indicator are relied upon; the directional gyro and the gyroscopic horizon are essential in maintaining a straight, level course.

Many experimental instrument landings have been made successfully at airports. Emergency instrument landings at airports are possible today; landings made regularly in poor visibility seem to be just around the corner.

Automatic Instrument Landing

The Army Air Corps has recently announced the development, and the successful use, of a method of making automatic instrument landings[10]. In this method the airplane is maintained in straight, level flight by the automatic pilot on a course determined in succession by four radio transmitters installed in approximately a straight line. The rate of descent to a selected altitude when between radio transmitters 2 and 3, and down to the ground, after passing transmitter 3, is held at 400 feet per minute by using a rate-of-climb indicator to control the throttle of the engine. When the predetermined altitude between transmitters 2 and 3 is reached, the throttle is brought to "no rate-of-descent" position by a control operated by the altimeter. Thorough experiments determined that the air speed, at this rate-of-descent with the airplane maintained in the flight-level position, is about 20 m.p.h. greater than the stalling speed. The airplane radio receiver is tuned automatically to the next radio transmitter by a control operated by a radio marker beacon when above each transmitting station. Upon landing a control is provided which automatically closes the throttle and applies the brakes.

This is a big step forward, especially in view of the claim made that the method can be adapted for use on any of the radio landing systems now in experimental use.

Power Plant Instruments

Centrifugal, chronometric, and less generally, magnetic tachometers[11] for measuring rate of rotation of the engine are used when the flexible shaft is not too long. In large airplanes it is necessary to use electric tachometers. A number of electric types are available, among which are (*a*) d-c. generator-voltmeter, (*b*) a-c. generator - d-c. indicator with electrolytic rectifier, and (*c*) a-c. generator - a-c. motor coupled to a centrifugal mechanism. Most electrical indicators have a minimum pointer motion of 270 degrees. A scale sufficiently open to indicate changes of at least 10 r.p.m. is essential. On multi-engined airplanes speed synchronizers are used, usually flashing a light at a rate proportional to the difference in speed.

Vapor-pressure thermometers are used to measure the oil temperature and, in air-cooled engines, thermocouple thermometers to measure cylinder-head temperatures. The latter instruments probably require anti-vibration mounting to eliminate a gradual shift in their calibration in service. There is a trend toward electric thermometers, either the resistance type or one using Selsyn or Autosyn transmitters, for measuring oil temperature.

Pressure gages of the Bourdon tube type are used to measure the fuel and oil pressure. The availability of electric types has been announced.

Fuel quantity is troublesome to measure when shallow wing tanks are installed. In one instrument[11] a tube extends to the bottom of the tank and is connected to a differential pressure gage and a hand pump. The latter forces air through the tube into the liquid whereupon the fuel head is just balanced by the air pressure in the tube and is indicated on the pressure gage, calibrated in fuel quantity. A check valve is usually installed in the line near the tank. In other instruments a float indicates the fuel level. Various means are used to indicate the float level at the instrument board. One, now little used, is by means of a mechanical connection, another by an indicator in an electrical circuit containing a resistance controlled by the float, and another by two Selsyn or Autosyn motors, one float-controlled, the other on the instrument board.

Manifold pressure gages are simply aneroid barometers adapted to indicate in the range 10 to 50 inches of mercury.

In the realm of less commonly used instruments are fuel flow meters, torque meters and fuel-air ratio indicators. Bridled-vane fuel flow meters using Autosyn motors have been developed by Pioneer; sink types[11] in which the impact pressure of the fuel on a ball in a tapered tube is balanced by the weight of the submerged ball, are suitable only for experimental use; orifice types are not available because simple, light and reliable means for distant indication are not available. Torque meters for measuring engine torque are available for experimental use only. Cambridge and Breeze fuel-air ratio indicators[12] analyze the exhaust gas by measuring its thermal conductivity and are calibrated in terms of the input fuel-air ratio. These are used by a num-

ber of aircraft operators. A limit to the usefulness of the fuel-air ratio indicator is that the lean end of the scale does not go far enough and that when beyond this range the indication again increases.

Ice Warning

Warning of the conditions under which ice may form on airplanes during flight is given by an indication of the humidity and air temperature of the free air. No satisfactory method of indicating high relative humidity is available. Air temperature is indicated either (*a*) by a bimetal thermometer installed on the airplane so as to be exposed to the free air and visible to the pilot, or (*b*) by a vapor-pressure thermometer with the bulb in the free air stream and the indicator on the instrument board. The use of the latter instrument to measure low temperatures has been made possible by using Freon as the filling liquid.

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II-Automotive

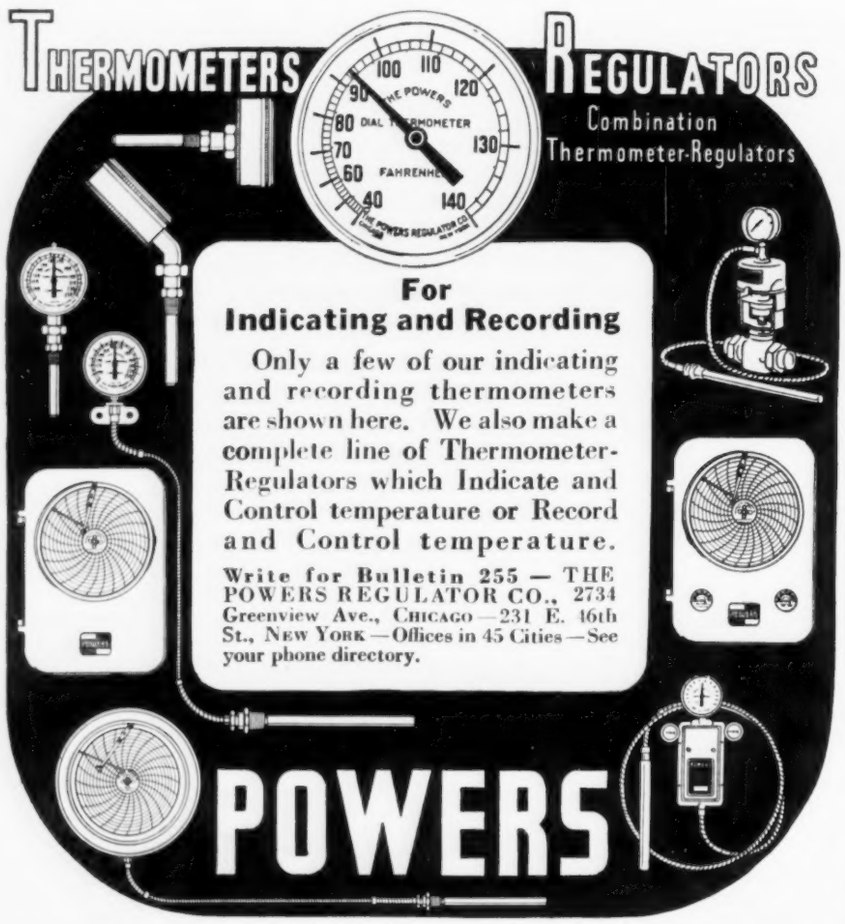
By W. G. BROMBACHER

National Bureau of Standards

INSTRUMENTS on the dashboard of the modern passenger automobile are characterized by simplicity of design and on the whole by qualitative rather than quantitative indications. In most automobiles an oil pressure gage, a cooling water thermometer, a fuel quantity gage, an ammeter, and a speedometer-odometer unit (and optionally a clock) comprise the instruments visible to the driver. Occasionally a "gadget" such as a magnetic compass, accelerometer, or altimeter, will be added by the owner. The factory-installed instruments are outstanding examples of competitive mass production in which all possible corners have been cut to obtain a low unit cost. Two instruments are discussed.

The speedometer is ordinarily of the magnetic type; the percent accuracy is ordinarily low as measured by industrial instrument standards; a one-mile error at 25 m.p.h., certainly not considered excessive, is a 4% error. The odometer is ordinarily much more accurate; the only error arises from changes in the overall tire diameter.

The fuel quantity gage must be of the distant-indicating type. Methods of securing distant indication have been under constant exploration. At present electric types are predominant. The K-S instrument[13] is of interest since the method uses the deflection obtained from a float in the tank, to control the heating effect of an electric current to obtain an equal deflection of two bimetals, one at the tank and the other at the indicator. The method can be used also to measure the oil pressure and the cooling water temperature in competition with the customary instruments. Another electric type has a double-coil indicator, one coil of which is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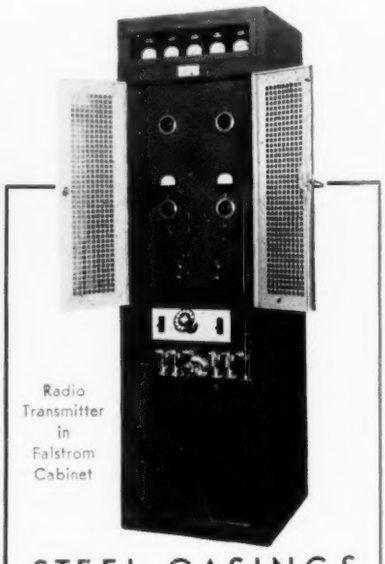

connected to one part of a divided resistance coil and the other coil to the other part. The point of division of the resistance coil is varied by the motion of the tank float. Both types are independent of applied voltage within wide limits.

It is noteworthy that no dashboard instruments indicate water level in the radiator or oil level in the crankcase.

Not generally known to many car operators is the fact that the modern car has many automatic controllers, some of which of course are not installed on all cars. Thus, the charging rate of the battery is controlled so as not to be excessive at high speeds; a thermostat is used to obtain a greater charging rate at low generator temperatures; a cutout prevents current passing through the generator when the generator is not being driven; a valve controlling the circulation of the cooling water in the radiator is operated by a vapor-pressure type thermostat so that the circulating water by-passes the radiator until the water in the engine is heated to a minimum temperature (between 140 and 160°F.); the intake gas is heated by the exhaust gas to a selected temperature determined by a bimetal thermostat; the ignition timing is automatically controlled by two elements, one responsive to the suction in the manifold and the other to the engine speed; and another combination—bimetal thermostat sensitive to engine temperature and pressure element sensitive to manifold pressure—controls the operation of the carburetor choke. These controls, and others, all lead to less hit-or-miss operation and to increased economy and reliability.

On trucks and buses instruments in addition to those listed for automobiles are installed. Among these are air pressure gages if air brakes are used, hub odometers, and door-closed indicators on buses. Speed controllers are sometimes installed. Desirable for safety is an instrument (under development) to indicate on the dashboard loss of tire pressure.

Vehicle instruments and controllers of the future are those needed in the air-conditioning of automobiles. Automatic controllers will undoubtedly be emphasized.

Maintenance of automotive vehicles has led to the use of instruments previously available such as the hydrometer for testing batteries and pressure gages for measuring air pressures in tires. Later developments are spark plug testers; battery testers depending upon the current delivered; portable decelerometers for measuring effectiveness of brakes; apparatus for adjusting brakes with associated instruments; apparatus with a "dial gage" for measuring front wheel alignment; head-light tests; exhaust-gas analyzers, usually of the thermal conductivity type, for determining richness of the intake fuel-air mixture; suction gages for checking manifold pressure; and ignition coil testers.

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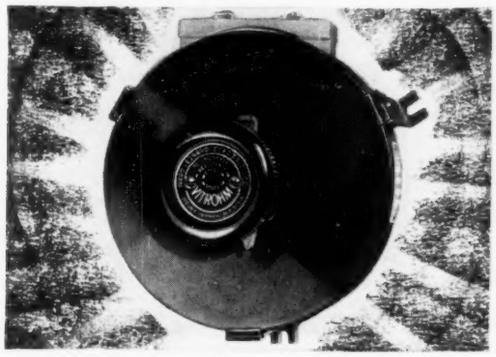
III-Rail

By L. O. GRONDAHL

Director of Research and Engineering, Union Switch & Signal Co., Swissvale, Pa.

FROM the first surveying of the road to the operation of regular scheduled trains, engineers and operators depend on instruments. Surveying requires accurate determination of angles, curves, grades, banking of the tracks, leveling, and every type of measurement needed to determine the geometrical relations involved in laying out a road bed.

When building is begun, materials testing becomes important: hardness, tensile strength, transverse strength, ductility, temperature coefficients, porosity, density, Young's modulus, yield points, resistance to wear, all have to be determined in the materials that are used in the construction of tracks, bridges, and buildings. Studies of the mate-



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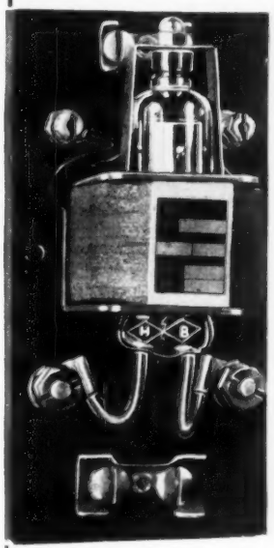

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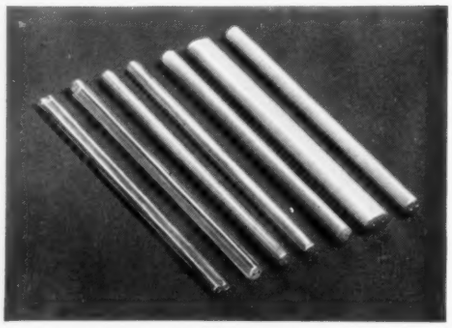

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rials involve the use of spectroscopes and spectrographs to determine composition; microscopes, microphotographs and X-rays to determine crystal structure, and to detect imperfections such as seams, laps, or cracks in the material which might reduce its corrosion resistance or physical strength.

Even more important are the studies and acceptance-tests of the materials used in building rolling stock such as cars and locomotives, whether the railroad is steam, electric, Diesel, turbine-electric or Diesel-electric. Moreover, every new design embodies the results of quantitative research in which numerous instruments are used, including such special ones as riding-quality accelerographs.

When we come to the actual operation of trains, we find entirely different sets of instruments, some used only for initial testing; others in regular operation. On a locomotive of whatever type there are speed indicators and recorders, and sometimes acceleration indicators. If the locomotive is operating over train-control or cab-signal territory, there is at least an automatic signal in the cab which indicates whether the track ahead is or is not occupied, or whether the circuit is opened for some other reason (such, for instance, as the dangerous condition of a broken rail). In locomotives equipped with train control, the signal apparatus coöperates with the speed indicator or the governor to actuate the brakes and takes the control of the locomotive out of the hands of the engine driver whenever he neglects to obey restrictive signals.

On a steam locomotive, in addition gages indicate boiler pressure, cylinder pressures, exhaust pressure, air pressures in the brake system and in the air reservoir. Other instruments indicate boiler furnace temperature, exhaust gas temperature and composition, and boiler water temperature and acidity. Gages show water levels in the boiler and in the tender; and alarms indicate when water level gets dangerously low.

On an electric locomotive we find, in addition to air-system instrumentation, a complement of ammeters, voltmeters, wattmeters, relays, signals and other items of electrical instrumentation.

On Diesel-electric locomotives, these are supplemented by fuel gages, oil pressure gages, fuel pressure gages, cylinder pyrometers and in some cases instruments to indicate the completeness of combustion such as CO_2 and CO indicators. On the new condensing steam turbine-electric locomotives, the instrumentation corresponds almost to that of a central station.

The braking of a train is safeguarded by different kinds of automatic-control apparatus: (1) to regulate the braking effort in accordance with speed—or rate of retardation—of the train; (2) to release the brakes on an axle automatically when the wheels of that axle begin to slide; (3) to regulate brake application at the forward end of a long freight train so that the braking of the different parts of the train will be applied more nearly at the same time and with more nearly uniform effect; (4) to retard the release of brakes at the front end of the train so that there will be no danger of one end running away from the other. Recording pressure gages are used in different parts of the train to check the functioning of the different parts of the brake apparatus.

On the wayside there are many auxiliary kinds of instrumentation. First of all, the automatic signaling system indicates to the engine driver whether he can safely proceed without interfering with other trains. Fire alarms attached to bridges set a stop signal for any train approaching a bridge on fire; high-water alarms do the same when the water reaches a certain level under the bridge. There are automatic switches and spring switches; as well as detectors to show when a switch is properly aligned and to prevent the setting up of a "proceed" signal at a switch unless it is properly aligned. Detectors check the alignment on tracks and bridges and other places where landslides or other forces might produce unsafe track conditions. There are slide protectors—fences which automatically set up a stop indication if a rock, which has rolled down a hill-side

towards the track, has struck the fence, or if a landslide has likewise approached the track. Highway crossing protection may be used to indicate to motorists that a train is approaching a crossing, or may be used to interpose a barrier between the automobile driver and the track. There are likewise automatic interlockings for producing a corresponding indication for trains crossing at grade. The wayside equipment includes detectors which, when equipment on the train is dragging dangerously, sets up a stop indication or applies the brakes to the train itself.

In territory where the traffic is congested, such as elaborate yards or multiple-track roads with many cross-overs, the traffic is often protected by what is known as an interlocking plant, in which all the switches and signals are controlled from a central office. The apparatus is so arranged that when a route is set up for a train to pass through the territory, the setting up of a conflicting route is not possible, hence the term "interlocking." This makes it possible to transmit frequent trains through the territory without danger of collision. In such a plant hundreds of pieces of apparatus measure the appropriate voltages or currents and respond with the indicated operation.

In more extensive territories, such as long stretches of single-track road with many passing sidings, a similar result is accomplished by "centralized traffic control," in which a pair of wires strung along the railroad carries coded current whereby the location and the desired condition are selected. When the change in condition desired at the office has been set up, the apparatus automatically reports back so that the office operator gets an indication.

Both in an interlocking plant and in a C.T.C. plant, the operator is provided with a plan of his portion of the railroad. This plan, on a board, is "animated" in that it indicates the position of all switches and signals as well as the progress of a train through the plant, thus keeping the operator at all times informed of the condition of the road and of the traffic.

Electric trains are provided with remotely-operated circuit controllers and indicators that the controllers have functioned; automatic breakers to open the circuit when some condition produces an overload; also remotely-controlled accelerators and remotely-controlled brakes, each of which indicates by two telemetering circuits that they have or have not operated.

On an electric train there are various types of braking: Regenerative brakes connect the motors as generators so that they serve as a decelerating means. Air brakes are similar to those used in steam-road territory. Eddy-current brakes are controlled by controlling the field of an electromagnet which produces the eddy current in a disk or a wheel. Track brakes consist of electromagnets held magnetically against the rail to produce frictional resistance. These braking systems are applied singly or in multiple in any desired combination under the command of instruments which respond to the speed of the car or train, the deceleration desired or existing, and the degree of brake application by the operator.

Air-conditioning equipment on passenger trains depends altogether for its proper functioning on instruments which automatically control temperature, air flow and humidity.

In the load dispatcher's office of an electrically operated road, there are telemeters, load indicators, synchroscopes, and other apparatus to determine at all times what parts of the load are being supplied by different generating stations, and what parts are being used in different sections of the road. The dispatcher is enabled thereby to distribute his load. This he does by means of instrumentation for remotely controlling the starting and stopping of generators, the connecting-in of transformers, and otherwise the controlling of all the power machinery at different generating or transforming stations.

The power stations, as well as the locomotives and multiple-unit cars, are provided with equipment to automatically cut out and isolate any part not functioning properly or subjected to unsafe conditions. This equipment provides against over-temperatures through thermal control; failure

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of cooling equipment, also through thermal control; the maintenance of voltage and phase relations between different parts of the circuits; overload, and in general any type of undue strain or failure. Without this elaborate instrumentation, it would be well-nigh impossible to operate the extensive and complicated power systems required for modern electric railway operation.

Many instruments of an auxiliary nature are required in rail transportation. For instance, the Sperry rail car is used to inspect rails in place—both at once— to detect incipient cracks and automatically mark either rail at any point that has a flaw. Another special auxiliary is the shock recorder or ride-quality recorder used in freight cars to check on the care of handling.

In some of the apparatus described, vacuum tubes are employed and they have to be checked frequently. This requires many different measurements in order to determine all the essential characteristics.

All instruments responding to some measured variable have to be maintained at a definite sensitivity and at a definite accuracy tolerance. This requires standardizing laboratories in which they can be checked against standards. Since the complete operation of a railway system depends on instruments, the standardizing laboratory has become one of the most important parts of the railway operating system.

It will be seen that the whole economy, reliability, and safety of rail transportation is dependent on the functioning of apparatus and instruments. The reliability of all materials, the adjustment of all the intricate apparatus so as to provide satisfactory co-operation, the information in regard to the functioning of all apparatus, to the condition of all essential parts of the system and to the location of all trains, make it possible to carry on this important branch of communication and transportation economically and safely.

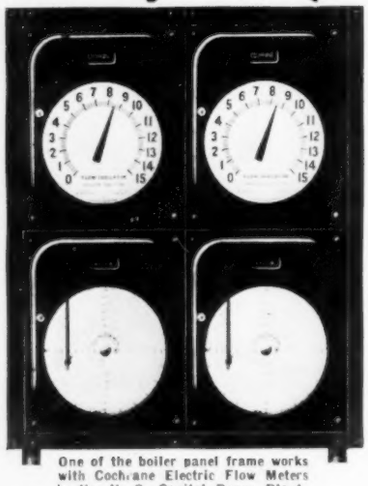
What Instruments Do for the Food Industries

(Concluded from page 18)

foods for which minimum color values have been established under the Federal Laws. Hydrometers on the Brix, Balling or Salometer scales find use in determining the percentage of soluble solids in the liquid packing medium. Electrometric and to a limited extent colorimetric pH instruments are in frequent usage for canned food inspection. Various types of viscosimeters are required for measuring the consistency of the product which often constitutes an index of quality. Abbé and immersion type refractometers, specific gravity balances or picnometers are needed to check the total solids of tomato purée and paste to make certain that all batches meet the specifications of the grade for which the product is being sold.

In addition to the foregoing instruments, the investigation of spoilage problems necessitates the use of more highly diversified instruments. The use of gas analysis units to test the gases in the headspace of the can serves to indicate whether the spoilage was due to bacterial growth or chemical action. Bacteriologists rely upon the microscope and the thermally controlled incubator to detect and grow the microorganism suspected of having caused canned food spoilage. From the morphology of the isolated organisms, the food bacteriologist can determine whether understerilization or failure of the hermetic closure was the causative factor involved in the spoilage investigation. The centrifuge also aids the bacteriologist in concentrating pure cultures of food spoilage bacteria to enable further study of their resistance to chemical and physical treatment. It is common practice when encountering food spoilage to strip the top and bottom seams from the cans involved in the investigation and measure their dimensions by means of a micrometer to make certain that faulty seam formation did not contribute to the spoilage.

Metering Steam for



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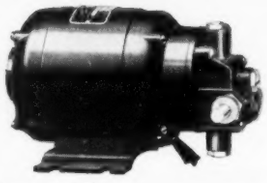

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For thermal studies, potentiometers fitted with scales reading directly in degrees Fahrenheit are used in conjunction with especially designed copper-constantan thermocouples for determining the rates at which conventional or newly formulated products conduct or convey heat from the heating medium to the slowest heating areas of the can contents. Heat penetration data obtained by means of these instruments permit graphic interpretation of the temperature/time relationship, the latter component being determined through the use of chronometers. Determining the sterilizing value of a specific thermal process in some instances involves integration of the heating-cooling curves which is facilitated through the use of the planimeter.

Only brief mention has been made of the many instruments that the canner relies upon in regulating and controlling canning procedures. Perhaps this discussion will serve to acquaint those engaged in other fields of scientific endeavor with the wide application of instruments in this industry. If the present trend is an indication of future developments, it is not unreasonable to predict that the next step in many of the applications is the extension of the use of continuous recorders. Such instruments permit uninterrupted and permanent records of the time and temperature phases of canning technique which are important factors in retaining color, flavor and texture.

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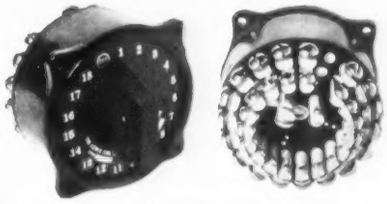

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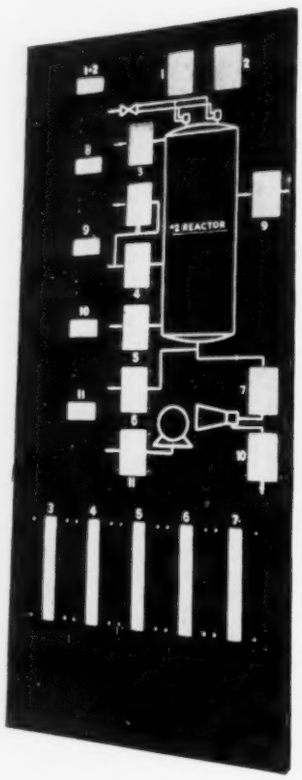

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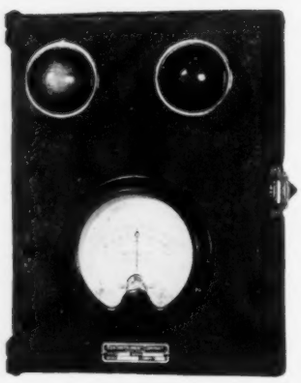

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